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A comparative analysis of commercial off-the-shelf naval simulations and classic operations research models

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THESIS

A COMPARATIVE ANALYSIS OF COMMERCIAL OFF-THE-SHELF NAVAL SIMULATIONS AND CLASSIC OPERATIONS RESEARCH MODELS

by

Peter A. Field

September 2009

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13. ABSTRACT (maximum 200 words)

No longer does Naval Surface Warfare merely entail battle between symmetric naval fleets conducted in large open water engagements. Today's Surface Warriors must have the training and capability to also fight asymmetric threats in congested locations of strategic value. Operations conducted within straits, choke points, and island cluttered littorals pose considerable risk and numerous challenges for today's Navy. Shore based anti-ship missiles, torpedo and missile carrying small fast patrol boats, and mines present capable threats across naval warfare areas such as Anti-Surface Warfare and Mine Warfare. In addition, conventional and midget submarines present an ever-growing threat within strategic littorals.

Previous studies have generated high-end simulations to determine composition of blue force fleets, and suggested tactics for addressing various modern threats. This thesis compares how well off-the-shelf simulation software in the form of Larry Bond's HARPOON3 Advanced Naval Warfare (H3 ANW) emulates high-end simulations validated through modified Hughes' Salvo Equations.

The results demonstrate the complexities involved in comparing the output of two completely different analytical tools. The mathematical nature of Hughes' Salvo Equations provides a focused deterministic aspect; while the dynamic interaction of platforms, environments, and tactics designed into H3 ANW provide a completely different aspect with potential use as a learning tool for Surface Warrior.

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A COMPARATIVE ANALYSIS OF COMMERCIAL OFF-THE-SHELF NAVAL SIMULATIONS AND CLASSIC OPERATIONS RESEARCH MODELS

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LIST OF ACRONYMS AND ABBREVIATIONS

AAW	Anti-Air Warfare
ASCM	Anti-Ship Cruise Missile
ASUW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
C2	Command and Control
CIWS	Close-in Weapon System
CSG	Carrier Strike Group
DB	Database
DP	Damage Points
ECM	Electronic Countermeasures
EMCON	Emission Control
ESG	Expeditionary Strike Group
ESM	Electronic Support Measure
FC	Fire Control
FER	Fractional Exchange Ratio
FP	Force Protection
FPB	Fast Patrol Boat
FRIFOR	Friendly Force
HVU	High Value Unit
IR	Infrared
IRGN	Iranian Republican Guard-Navy
ISR	Intelligence Surveillance Reconnaissance
JFS	Jane's Fighting Ships
LCS	Littoral Combat Ship

MANA	Map Aware Non-Uniform Automata
MCM	Mine Countermeasures
MOE	Measure of Effectiveness
MPA	Maritime Patrol Aircraft
MW	Mine Warfare
OPDEF	Operational Defect
OPFOR	Opposing Force
PDMS	Point Defense Missile System
PGFG	Missile Fast Patrol Boat
PTF	Torpedo Boat
PTG	Missile Boat
RAM	Rolling Airframe Missile
RCS	Radar Cross Section
SA	Situational Awareness
SAG	Surface Action Group
SAM	Surface-to-Air Missile
SLOC	Sea Lanes of Communication
SSC	Coastal Submarine
SSK	Conventional Submarine
SSM	Surface-to-Surface Missile
TF	Task Force
TG	Task Group
UAV	Unmanned Aerial Vehicle
VLS	Vertical Launcher System
WHP	Weapon Hit Probability
WLR	Weapon Launch Reliability

EXECUTIVE SUMMARY

As the focus shifts away from high sea engagements, the U.S. Navy must deal with confrontations where tactics involving asymmetric warfare are becoming the norm. The use of smaller, faster, easily mass produced vessels carrying heavier payloads in the form of surface-to-surface missiles (SSM) to attack larger opponents in key strategic near shore and confined waterways has forced the United States Navy to reevaluate its tactics.

This thesis looks at littoral engagements between Friendly Forces (FRIFOR) and Opposition Forces (OPFOR) through the use of a commercial, off-the-shelf naval simulator that is readily available for public use; *Harpoon3 Advanced Naval Warfare* (H3 ANW) produced by Matrix Games. The goal was to determine how well the H3 ANW simulation software emulates high-end Operations Research methods, and discern whether it can provide valuable insight regarding operational concepts, tactics, battle space utilization, and the littoral threats faced by today’s United States Navy.

Addressing previously tested scenarios, this thesis sought to reproduce results within a simulated environment and attempted to ascertain what insights can be gained by testing new approaches within these scenarios. Mission scenarios applicable to modern day real-world threats were developed using the Harpoon3 (H3 ANW) simulation software Scenario Editor. An analytical comparison was conducted on

scenario outcomes between the simulation software results and similar results produced from the thesis work conducted by Ozdemir (2009).

This study directly benefits decision makers interested in identifying and benefiting from a cost-effective, readily available aggregated learning tool, with the potential to provide tactical insights into modern threats. The opportunity to simulate tactics and potential counters in challenging realistic scenarios such as littoral warfare can provide surface warriors a detailed learning environment.

The key to the flexibility of H3 ANW is its database. Modular in design, it provides the information necessary to produce realistic models. Built upon the two original formulas developed by Larry Bond to first, determine a ship's damage point value based on the ship's tonnage with modifications allowing for ship type and construction methods; and second, determine the damage inflicted with a weapon system based on the warhead's weight.

The scenario analyzed an encounter of Friendly Forces (FRIFOR) and Opposition Forces (OPFPR) in the Strait of Hormuz. However, its littoral environment is surrogate to strategic choke points throughout the world. The model’s outcome depicted littoral warfare operations in confined waterway where numerous islands and bays provide havens for small boat operations. These tactics have proven deadly for many conventional ships resulting in navies around the world adapting by adopting smaller, lighter, cheaper, and stealthier ships with greater capability to overcome asymmetric multi-axis threats.

Five types of Iranian naval vessels were considered in this analysis, each capable of carrying surface-to-surface missiles or torpedoes. There were two classes of submarines carrying torpedoes, one conventional and one midget; two classes of missile carrying Fast Patrol Boats; and one class of Fast Missile Boat. Initially, the FRIFOR squadron was comprised of the Littoral Combat Ship (LCS). After that engagement was modeled, Russian Steregushchiy frigates replaced LCS in the model. The scenario results for each FRIFOR platform were compared and evaluated.

The dynamics of real-world interactions within the model, environmental factors and geography affecting platform performance, provided great insight into considerations that must be addressed in combat operations. H3 ANW provided an excellent tool for experimenting with how these factors can affect a mission’s outcome. While difficult to design, creating or modifying platforms allowed the user to learn the strength and weaknesses of various platforms and weapon systems. The platforms designed in this model display very real threats the United States Navy faces within strategic choke points and littorals. The asymmetrical OPFOR threats present in the Strait of Hormuz were displayed, and used to demonstrate what FRIFOR tactics provided the greatest probability for mission success.

H3 ANW produced a dynamic model demonstrating interactions between overlapping OPFOR patrol areas and weapon ranges. It allowed FRIFOR platforms to use specific tactics when engaging OPFRO threats. It demonstrated that using dedicated anti-submarine warfare and anti-surface warfare defined missions and tactics marked a profound difference in the outcome of each run executed. Whereas Salvo Equations provided insights through the use of mathematical calculations, and were instrumental in defining the scenario for this thesis; H3 ANW provided insights into specific platform capabilities and limitations, employed tactics, environmental factors, and geographic concerns when conducting operations within strategic choke points and littorals.

The Harpoon3 Advance Naval Warfare series of naval simulations provides an inexpensive aggregated training tool that can benefit today's United States Navy. It provides scenario based training that can be tailored to operations within specific geographical locations, demonstrate upcoming ship's evolutions, or educate leadership on scenarios currently in the news headlines (e.g., Somali pirate interaction, United Nations Resolution enforcement). The potential as a cost effective training tool to introduce surface warriors to the asymmetric threats they may face today has yet to be realized.

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Captain Wayne P. Hughes, USN (Ret.), provided the first look into what a Surface Warrior like me can do with the knowledge and tools learned here. It has left a lasting impression, and it was an honor and a pleasure to learn from a living legend within the community of my profession.

To my friends and classmates who suffered alongside me, the hours spent studying have left their mark, but the memories that remain are ones of friendships made. I never would have made it without you. To friends and shockstars who provided much needed tension relief, you are adored.

To ALL of my family but especially to my beautiful wife, Mariska, and our sweet babies, Drake, Lily, and Pierce, thank you for your support, love, and understanding. You make it all worthwhile. You are the source, and I love you.

I. INTRODUCTION

A. BACKGROUND AND OVERVIEW

The threats to today's United States Navy have changed. More accurately, they have shifted in strategy and tactics, and not in such a way as to be in the United States' favor. With the fall of the Soviet Union, the potential for a blue water, high seas confrontation has been reduced. While countries such as India, Russia, and China have navies capable of some projection of power beyond their immediate sphere of influence, their capabilities are limited in comparison to the strength and capabilities of the U. S. Navy. Where they, and many countries, can take advantage of their capability is within littoral waters.

As the focus shifts away from high sea engagements, the U.S. Navy must deal with new confrontations where tactics involving asymmetric warfare are becoming the norm. The use of smaller, faster, easily mass produced vessels carrying heavier payloads in the form of surface-to-surface missiles (SSM) to attack larger opponents in key strategic near shore and confined waterways has forced the United States Navy to reevaluate its tactics. The threats posed by mini and conventional subs targeting high-density traffic in strategic choke points require dedicated resources to ensure safe transit.

The United States Navy has developed the Littoral Combat Ship (LCS) specifically to operate within these regions, using tailored mission packages to counter potential threats. In coordination with larger naval forces outside of the littoral, the LCS is designed to combat adversaries in challenging environments while supporting a Carrier Strike Group (CSG) or Expeditionary Strike Group (ESG) and protecting Sea Lanes of Communication (SLOC) (RAND Study, 2007; CRS Report, 2008), see Figure 1.

A number of Naval Postgraduate School (NPS) theses have studied the challenges associated with littoral environments (Tiwari, 2008), how LCS compares to similar platforms in other navies when conducting operations in littoral environments (Christiansen, 2008; Ozdemir, 2009), and in what size and mission package diversity an LCS Surface Action Group (SAG) or squadron should operate (Abbott, 2008; Milliken, 2009). To this end, traditional Operations Research (OR) methods have been used to conduct evaluations and analysis.

In-depth calculations using Hughes' Salvo Equations (Hughes, 1995) have provided analysis on survivability and cost effectiveness of LCS against relatively inexpensive asymmetric threats faced in strategic choke points such as the Strait of Hormuz. High-end simulations, such as MANA (Map Aware Non-Uniform Automata), an agent-based distillation model commonly used by military operation analysts, have provided decision makers with visual representations in analyzing and determining LCS SAG operations (Abbott, 2008). The purpose of this thesis is to look at similar engagements between Friendly Forces (FRIFOR) and Opposition Forces (OPFOR) using a commercial off-the-shelf naval simulator that is readily available for public use. *Harpoon3 Advanced Naval Warfare* (H3 ANW) produced by Matrix Games, has been selected as the simulator of choice.

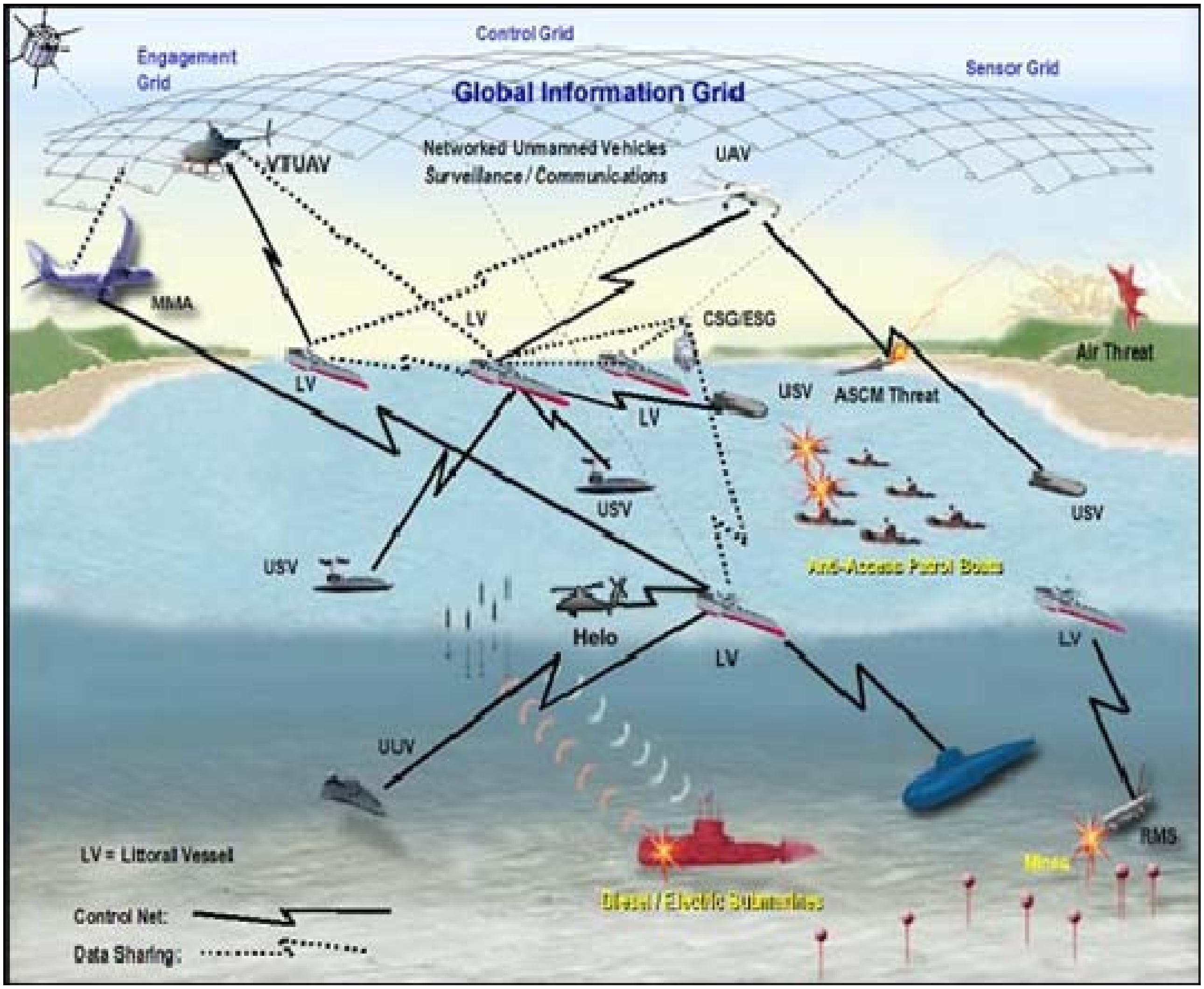

Figure 1. Pictorial display of the concept for LCS operations (From Joint Requirements Oversight Council 2004) (Best Viewed in Color)

B. THESIS OBJECTIVE

The goal of this thesis is to determine how well the off-the-shelf naval simulation software, *Harpoon3 Advanced Naval Warfare (*H3 ANW*)*, emulates high-end Operations Research methods, and discern whether it can provide valuable insight regarding operational concepts, tactics, and battle space movement of surface combatants.

C. RESEARCH QUESTIONS

- How does the more economical, off-the-shelf simulation software compare to traditional Operations Research (OR) methods in accuracy, usefulness to the decision maker, and operability?
- Can it be used to emulate the results of traditional OR techniques, such as Hughes' Salvo Equations and provide an accurate simulation or visual representation of a defined scenario?
- Can the simulations produced by the off-the-shelf software demonstrate or test potential tactical improvements for real-world scenarios?
- Can recommendations such as tactical formations for missile combat be determined and displayed to decision makers?
- Can simulation software be used to demonstrate in-depth defense strategy, emphasizing soft kill or stealth properties?
- Can the simulation software produce a reliable scenario involving Opposing Force (OPFOR) submarines?

D. SCOPE OF THESIS

This thesis provides a comparison and contrast of affordable and readily accessible simulation software, and its ability to plan and provide tactical insights for the littoral threats faced by today's United States Navy. It addresses previously tested real-world scenarios, and seeks to reproduce results within a simulated environment. Additionally, it is the goal of this thesis to see what insights can be gained by testing new tactical approaches within these given scenarios.

E. RESEARCH METHODOLOGY

Mission scenarios applicable to modern day real-world threats are developed using the Harpoon3 (H3 ANW) simulation software Scenario Editor. An analytical comparison is conducted on scenario outcomes between the simulation software and results produced from the thesis work conducted by LTjg Omur Ozdemir, (2009) *Evaluation and Comparison of Freedom Class Littoral Combat Ships (LCS) and Corvette-Frigates Around the World in Surface Action Group (SAG) Against Small Boat, Fast Patrol Boat (FPB) and Submarine Threats in Confined Waters*. The modified Hughes' Salvo Equations used have been validated with the guidance of Professor Wayne P. Hughes, CAPT, USN (Ret.).

F. SIGNIFICANCE OF RESEARCH

This study directly benefits decision makers interested in identifying and benefiting from a cost-effective, readily available aggregated learning tool, with the potential to provide tactical insights into modern day threats. The opportunity to simulate tactics and potential counters in challenging real-world scenarios such as littoral warfare can provide surface warriors with a safe and detailed learning environment.

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II. HUGHES' MODIFIED SALVO EQUATIONS

A. INTRODUCTION

Basic Salvo Equations, developed by CAPT Wayne E. Hughes, USN (Ret.), deal with the representation of missile exchange between warships using surface-to-surface missiles (SSMs) and surface-to-air missiles (SAMs) (Hughes, 1995). Building on the basic Salvo Equations, several theses have used modified versions of the Salvo Model to compare Friendly Forces (FRIFOR) and Opposing Forces (OPFOR) engagements. Specifically, these models have been designed to represent a weapon exchange and defense encounter between homogenous forces (Hughes, 1995; Hughes, 2000).

In the development of the scenarios used for this comparison, the OPFOR by design was heterogeneous, with values assigned to produce homogenized attributes. The resulting homogenized attributes that appear in the formulas were validated by CAPT Hughes during discussions, and helped develop the engagement scenarios. Additionally, Anti-Ship Cruise Missile (ASCM) "leakers" were introduced into the modified Salvo Equations as an expansion on earlier work (Hughes, 2000). The detailed information on FRIFOR and OPFOR forces, the process in choosing their attributes, as well as the analysis and results, are covered in later chapters.

B. MODIFIED SALVO EQUATIONS

The modified force-on-force equations for combat engagements, achieved by a single weapon salvo fired by a homogenous or homogenized force at any time step, are the following:

$$\Delta B = \frac{(\alpha' A - b_3' B) b_4}{b_1} \qquad (1)$$

where,

A = number of ships in force A

B = number of ships in force B

ΔB = number of ships in force B out of action from A's salvo

b_4 = Seduction Countermeasures Effectiveness

b_1 = number of hits by A's missiles needed to put one B out of action

$$\alpha' = \sigma_A \tau_A \rho_B \alpha \qquad (2)$$

where,

α' = fighting power in hits of an attacking A modified for scouting and training deficiencies and the effect of defender B's distraction countermeasures effectiveness

σ_A = Scouting Effectiveness of A

τ_A = Training Effectiveness of A

ρ_B = Distraction Countermeasures Effectiveness of side B

α = number of well-aimed weapons fired by each A ship

$$b_3' = \delta_B \tau_B b_3 \qquad (3)$$

where,

b_3' = hits denied to A by defender counterfire of B, degraded for defender alertness and training deficiencies

δ_B = Defensive Readiness/Alertness of B

τ_B = Training Effectiveness of B

b_3 = number of well-aimed weapons destroyed by each B ship

$$\Delta A = \frac{(\beta' B - a_3' A) a_4}{a_1} \tag{4}$$

where,

$$\beta' = \sigma_B \tau_B \rho_A \beta \tag{5}$$

$$a_3' = \delta_A \tau_A a_3 \tag{6}$$

The corresponding terms and terminology hold for equations (4), (5), and (6), i.e., replace A with B, α with β and vice versa(Christiansen, 2008; Ozdemir, 2009).

C. DEFINITIONS OF MODEL PARAMETERS AND ASSUMPTIONS

1. Striking Power (α, β)

Striking power is the number of well-aimed offensive weapons fired by each ship in the Basic Salvo Equations designed for missile exchange. The scenarios analyzed in this thesis, however, require that the offensive weapons represented in the Modified Salvo Equations be short and long range SSMs and torpedoes. For each encounter and weapons exchange, it is assumed that both sides’ offensive weapons are within each others’ effective firing range. The number of well-aimed weapons is calculated using the number of ready-to-fire weapons on board, the Weapon Launch Reliability (WLR), and the Weapon Hit Probability (WHP). This, therefore, may result in a non-integer number represented by the equation

Striking Power = Number of Weapons * WHP * WLR (7)

The number of weapons is considered the number of ready-to-fire weapons, i.e., Harpoon long-range SSM canisters or the number of torpedo tubes on ships and submarines, and does not include a reload capability of the platforms. WLR is the probability that the fired weapon will leave its launcher successfully. WHP is the probability that the fired weapon will achieve a successful hit on its target, where the target's defenses are not taken into account.

For both forces and all ship and weapon types, the WLR is assumed 0.9. The WHP assumptions for the weapon types are as follows:

Weapon Type	**WHP**
Torpedoes	0.9
Short Range SSMs	0.8
Long Range SSMs	0.7

Table 1. Offensive Weapon Hit Probabilities

2. Defensive Power (a_3, b_3)

Defensive power is the number of well-aimed weapons destroyed by each ship. Basic Salvo Equations factor in the SSMs and SAMs. In recent theses, defensive power has been investigated in depth, focusing on the types (Infrared (IR), active or semi-active radar homing) or lack of SAMs, number of Fire Control (FC) channels, as well as defense against torpedoes. Defensive power of a ship is different for each type of offensive weapon. The parameter in the formula can be a non-integer number (Ozdemir, 2009).

3. Staying Power (a_1, b_1)

Staying power is the number of hits needed to put a ship out of action. In other words, this is the number of hits that can be absorbed before a ship’s Combat Power is reduced to zero. Combat Power is defined as striking power minus a target’s defensive power. A ship put out of action does not necessarily mean it is sunk; rather, it means it is either a neutralized threat or a firepower kill. The hits required to put a ship out of action linearly diminish her fighting strength. Staying power is dependent on the type of weapon (torpedo or missile) that hits, therefore the staying power of each ship is different against each type of weapon, and the parameter can be a non-integer number.

4. Scouting Effectiveness (σ_A, σ_B)

Scouting effectiveness is the degradation of striking power measured in hits per salvo. This degradation is due to imperfect detection or tracking of enemy targets. It can be described as the level of efficiency regarding the collection of enemy targeting information for a successful attack. The parameter takes a value between zero and one, one being 100% effective. A modern frigate with effective radars and organic air assets for scouting should have a targeting effectiveness of one. This can, however, degrade due to the target’s nature, e.g., small and hiding within clutter, such as other boats, land, etc.

5. Defensive Readiness (δ_A, δ_B)

Defensive readiness is the extent to which a targeted ship fails to take defensive actions to her designed combat potential. This may be due to unpreparedness, lack of a condition of readiness, or reduced readiness caused by enemy Emission Control (EMCON). The parameter takes a value between zero and one, one being 100% ready. A good example of low readiness is when the Israeli Eilat Class Corvette, INS Hanit, was not 100% alert due to operational and intelligence relaxations at the time Hezbollah attacked with a truck-mounted C-802 during the Israel-Lebanon conflict in 2006.

6. Training Effectiveness (τ_A, τ_B)

Training effectiveness is the degree to which a firing or targeting ship does not reach her designed combat potential due to inadequate training, organization or motivation. The parameter takes a value between zero and one, one being 100% effective. This number could portray the level of professionalism of the crew, level of training, spare part and equipment technology constraints, etc. Scenarios can be developed using the assumption that OPFOR, such as the Iranian Navy, have a lower level of training effectiveness; if not due to professionalism, then certainly due to the number of obsolete ships in their fleet and the use of older equipment.

7. Seduction Countermeasures Effectiveness (a_4, b_4)

Seduction countermeasures effectiveness is defined as the level of success a targeted ship has in causing incoming weapons to miss. When an incoming weapon is homing onto a ship, the seduction phenomenon diverts the weapon away from the ship. This can be accomplished by using soft kill methods, such as the deployment of a decoy or chaff. These methods are enhanced when working in conjunction with physical features of the ship to reduce Radar Cross Section (RCS). Seduction chaff or a decoy create a non-existing target for the weapon to home in on, and are doubtless the biggest contributors to this parameter.

Seduction soft kill is a complementary element to conventional hard kill defense, i.e., SAMs. Other contributors may include stealth design, acoustic fingerprint or IR signature of the ship design, etc. Further, if combined with a seduction soft kill method such as creating a fake radar echo, a smaller RCS enhances the effectiveness of the soft kill method and increases the probability that a homing weapon will change course and engage the non-existent target. This parameter also takes a value between zero and one. This time however, one represents the worst case. This is due to the nature of the formulas. For example, a level of 0.85 would mean 15% of the incoming weapons would miss the ship due to seduction countermeasures effectiveness.

8. Distraction Countermeasures Effectiveness (ρ_A, ρ_B)

Distraction countermeasures effectiveness is the ability for a defensive platform to cause enemy shots to miss before use of defensive power. The purpose of distraction is similar to the seduction phenomenon. The timing, however, is different. Distraction happens preferably before the enemy fires its weapons and prior to the lock-on from incoming weapons. Certain soft kill methods create distraction. The attributes of the ship, however, also play a significant role.

Distraction chaff or creating a fake radar echo, used during the enemy’s scouting phase or even after its missile is fired, may cause the enemy to target or the incoming missile to lock-on a fake radar echo. The ship design features mentioned in seduction countermeasures effectiveness contribute even more to distraction countermeasures. For example, having a smaller RCS in situations where the enemy is far away, may reduce the enemy’s scouting effectiveness. The enemy may not be able to see the ship on radar or, if a contact is present, it may be confused or “distracted” about which contact to fire at due to an insufficient radar echo.

D. INTRODUCTION OF LEAKERS

To better represent real-world scenarios, the introduction of leakers into the modified Salvo Equations was deemed necessary. The concept of leakers can be summarized as: no matter how effectively a ship’s crew trains and fights and regardless of the superiority of her personnel, sensors and weapons, there is an amount of considered leakage from the incoming enemy weapons that cannot be engaged by any means (Hughes, 2000). A case in point is an AEGIS cruiser or destroyer, which has excellent coverage of air space with the 3D SPY radar, is armed with numerous SM-2 SAMs, has the maximum capability to reduce the leakers from an incoming swarm of cruise missiles, but still cannot assuredly eliminate all incoming missiles all the time.

Note that even if one side has superiority over another with zero ships lost in the Basic Salvo Equations, there still will now be some loss due to leakers. In the modified Salvo Equations, additional losses due to leakers are calculated using formula (8). Leakage rate is the percentage of the incoming weapons that survive defensive counterfire. The resulting value, therefore, is typically a non-integer number.

The number of losses due to leakers for side A adds to ΔA:

$$\text{Number of losses to Leakers} = \frac{B * \beta * \text{Leakage Rate}}{a_1} \qquad (8)$$

Leakage rate assumed for each weapon type is as follows:

Weapon Type	**Leakage Rate**
Torpedoes	0.15
Short Range SSMs	0.10
Long Range SSMs	0.05

Table 2. Offensive Weapon Leakage Rates

E. MEASURES OF EFFECTIVENESS

1. Fractional Exchange Ratio (FER)

The primary Measure of Effectiveness (MOE) used in these calculations is the FER. It compares the fraction of the two forces destroyed by the other under the supposition that they exchange salvos. Mathematically, the ratio of fractional losses after A and B exchange salvos is:

$$FER = \frac{\Delta B / B}{\Delta A / A} \tag{9}$$

FER indicates who wins the salvo exchange or if there is parity with losses on both sides due to leakers. When the FER is greater than one, side A has reduced side B by a greater fraction than side B has reduced side A. Thus, in a sense, side A has won because if things continue as is, it will have surviving units when side B is annihilated. When the FER is less than one, side B has the advantage of the exchange. If FER is between zero and one, side B wins, and, if FER is greater than one, side A wins. If FER is one, parity is achieved. The use of FER as a MOE is further discussed in later chapters.

2. Remaining Units after a Salvo Exchange

After a salvo exchange, the number of ships out of action is calculated from the modified Salvo Equations. Naturally, the number of ships put out of action has the lower bound of zero and the upper bound of the initial number of ships. Ships put out of action subtracted from the initial number of ships results in the remaining number of ships and is used as a secondary MOE. Thesis work conducted by LTJG Ozdemir looked into encounters and revealed the number of ships required to achieve a Breakpoint or Dominance. To achieve this, a fixed number of side B OPFOR ships was used against a variable number of side A FRIFOR ships; Breakpoint and Dominance are described as follows:

a. Breakpoint

Breakpoint for side A is achieved when the number of remaining A units is strictly greater than the number of remaining B units.

b. Dominance

Dominance for side A is achieved when the number of A units lost is minimized and the number of remaining A units is strictly greater than the number of remaining B units, which is zero.

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III. HARPOON3 ADVANCE NAVAL WARFARE (H3 ANW) SIMULATION

A. INTRODUCTION

This chapter provides detailed information on the development and use of the Harpoon simulation, originally created by Mr. Larry Bond.

Harpoon is the name of a comprehensive series of naval warfare games developed initially in miniatures by Larry Bond in the late 1970s, and moved to computer format in the 1980s. Computer Harpoon was derived from the paper rules for the original Harpoon miniatures game, which is played in a similar fashion to the popular role-playing game Dungeons & Dragons. Focused on naval warfare, it was originally designed as an anti-submarine warfare (ASW) training tool but eventually developed into all aspects of naval warfare.

Using only unclassified sources available to him at the time, *Jane's All the World's Ships* and *Combat Fleets of the World*; and his academic background, a bachelor's degree in quantitative methods; Bond created the Harpoon game system using two simple formulas. The first determined a ship's damage point value based on the ship's tonnage with some modifications to allow for ship type and construction methods. The second determined the damage inflicted with a weapon system based on the warhead's weight. Harpoon was born, and in 1982, was awarded war gaming’s equivalent of the Academy Award, the H. G. Wells Award. It was during this time that Harpoon began to receive strong support from the professional naval community and in 1984, Harpoon2 was published by Adventure Games (www.computerharpoon.com).

In 1987, Larry Bond signed a contract with a Texas-based firm, Applied Computing Services Inc., to begin programming the first Harpoon computer version. Thirty months in development, 12 man years of time, at a cost of over $300,000, the IBM DOS version of Computer Harpoon was published in 1989 by Three-Sixty Pacific Inc. Harpoon3 is a real-time naval war game at the tactical and operational level. It accurately models and simulates naval and air warfare with editable platforms, sensors, and weapons.

As the successor to the award-winning Harpoon2 and Harpoon Classic, Harpoon3 Advanced Naval Warfare (H3 ANW) is quite possibly the most comprehensive, realistic and highly accurate strategy simulation of air and naval operations available to non-military users. The Computer Harpoon series is considered to be close enough to "the real thing" that it has recently been under development with the Australian Navy to be used as a training aid H3 ANW uses Larry Bond's tabletop miniatures wargame Harpoon as its source. H3 ANW enables faithful modeling and representation of the full range of modern air and naval operations; including submarine & anti-submarine warfare, carrier battlegroup operations, convoy actions, land-based air operations, employment of nuclear weapons, amphibious and air-assault operations, massive fleet engagements and more. Additional features include: multiplayer support, third party databases, scenario editors, and more than 120 pre-built scenarios to enhance the potential insights to be gained by its use.

B. EQUATIONS

The key to the flexibility of H3 ANW is its database (DB). The DB is modular in design and provides the user with all the information necessary to make playing the game realistic. Figure 2 shows how vessels and aircraft are assigned Damage Points (DP) and Radar Cross Section (RCS) values based upon platform size. During scenario execution, these values are affected by a number of modifier values based upon variables such as: Target Noise modifier, Surface Gunnery modifiers, and even a Pilot Experience modifier. These modifiers, along with specific calculations for engagements, probability of hit, etc., provide the modified force-on-force equations for combat.

SIZE CLASSIFICATION TABLE

	Ship RCS (m^2)	Ship Dam Points	Aircraft RCS (m^2)	Typical Aircraft
Large	1,000,000	401+	100	Backfire
Medium	100,000	126-400	20	S-3 Viking
Small	10,000	0-125	5	F-15, B-1B
Very Small	1,000		0.1	Su-35, Rafale
Stealthy	100		0.01	B-2, F-117

Figure 2. Platform Size Classification Table

C. DEFINITIONS OF MODEL PARAMETERS AND ASSUMPTIONS

1. Striking Power

Striking power is defined as the number of well-aimed offensive weapons fired by each ship in the Basic Salvo Equations designed for missile exchange. Unlike with the Modified Hughes’ Salvo Equations, H3 ANW has no assumptions that both sides’ are within each others’ effective firing range during each encounter and weapons exchange. As with real-world engagements, the ability to hit an opponent is effected by a myriad of variables. H3 ANW also takes into account calculations for the attack platform and weighs them against characteristics of the attacked platform. With Salvo Equations, the number of well-aimed weapons is calculated using the number of ready-to-fire weapons on board, the Weapon Launch Reliability (WLR), and the Weapon Hit Probability (WHP). H3 ANW uses the full scope of weapons available to the platform involved in the engagement, while tracking the probability that the weapons system is still functioning. Figure 3 displays the damage ratio table.

DAMAGE RATIO TABLE

Damage Ratio	D6 Die Roll 1	2	3	4	5	6
<.10						1
0.10					1	2
0.20				1	2	3
0.30			1	2	3	4
0.40		1	2	3	4	5
0.50	1	2	3	4	5	6
0.60	2	3	4	5	6	7
0.70	3	4	5	6	7	8
0.80	4	5	6	7	8	9
0.90	5	6	7	8	9	10
1.00	6	7	8	9	10	11

Note: Higher ratios should be extrapolated.

Figure 3. Harpoon Damage Ratio Table

One of Larry Bond’s original formulas while developing Harpoon was to determine the damage inflicted with a weapon system based on the warhead's weight. Building upon this base formula, a series of modifiers and augmentations provide for the Striking Power in Harpoon. Figure 4 displays a general attack table.

GENERAL ATTACK TABLE

Target Type	Dmg Pts	Armor Level	Size Class	Critical hit result
A/C in open	5	None	Sm	Destroyed or damaged
A/C in revetment	15	Light	Med	Destroyed or damaged
Hangar	120	Light	Lg	1-3 aircraft inside are destroyed or damaged
Hardened aircraft shelter (HAS)	75	Heavy	Med	Structure is destroyed Aircraft inside is destroyed
Radar	25	None	VSm	No landings in visibility less than 1 nm. Landing rate halved
Control tower	50	Medium	Sm	Landing/takeoff rate halved
Maintenance	250	Light	Lg	Aircraft and runway repair chances halved
Magazines	125	Heavy	Med	D10*10% of one munition type destroyed (except there are an unlimited number of iron bombs)
Tank, Heavy	8	Med	Sm	Destroyed
Tank, Light	5	Light	Sm	Destroyed
APC	5	Light	Sm	Destroyed
Truck/Car	2	None	Vsm	Destroyed
AAA Gun	5	None	Vsm	Destroyed
Fixed SAM Lchr	8	None	Sm	Destroyed
Mobile SAM Lchr	5	Light	Sm	Destroyed

Figure 4. General Attack Table

2. Defensive Power

Defensive power is the number of well-aimed weapons destroyed by each ship. As stated previously, the defensive power of a ship is different against each type of offensive weapon. H3 ANW takes this into consideration and has developed cross referenced tables for probability of hit by offensive weapons, modified by defensive characteristics of each platform given a particular weapon——specifically, a platform’s capability to shoot down an incoming missile. Figure 5 provides an example of one such table used for Air Defense Gun Hit Chance Modifiers.

AIR DEFENSE GUN HIT CHANCE MODIFIERS

• Non-maneuvering aircraft (including ones "surprised" by gunfire) or surface-to-surface missiles above the VLow altitude band and slower than 1000 knots, double (2x) the hit chance.

• Target moving faster than 8.3 nm/Engagement Turn (1000 kts) reduce the hit chance by -10%.

• Crossing targets (≥90°/Engagement Turn) reduce the hit chance by 1/2.

• Antiship missiles that employ terminal maneuvers, including pop-up, reduce the hit chance by -15%.

• Sea skimming targets (in the VLow altitude band), reduce hit chance by 1/2, unless the gun system is listed as "sea skimmer capable."

• Guns in local control (OP mode), reduce the hit chance by 1/2. This modifier isn't applicable to gun systems whose only FC mode is optical (OP).

• Against a hovering helicopter, double (2x) the gun system hit chance. Do not apply the VLow modifier to hovering helicopters.

• If the aircraft uses self-protection jammers or chaff launchers during an attack, reduce the gun system hit chance by 1/2. This penalty is not applicable to gun systems with electro-optic (EO) sensors or those in the optical FC mode.

• In poor visibility (40% or less), reduce the hit chance of any gun in the optical (OP) FC mode by 1/2.

• If a large caliber gun (76mm+) fires in the Reaction Fire Phase, halve the hit chance.

• Targets at High altitude reduce the hit chance by 1/4.

• Target has a Very Small or Stealthy RCS reduce the hit chance by -15%.

• Three-Second Rule - If a missile is destroyed less than three seconds of flight from its target, the target will suffer fragmentation damage from the missile's warhead and structure. To find the fragmentation danger range (in nm) divide the distance traveled in one Engagement Turn Movement Phase for the target missile by 5. If the missile is destroyed at this range or less, it inflicts fragmentation damage (see section 7.3.1.2 Airbursts).

• *A gun's hit chance cannot be raised above 0.85. Minimum hit chance is 0.01.*

Figure 5. Harpoon's Air Defense Gun Hit Chance Modifiers

3. Staying Power

Staying power is the number of hits needed to put a ship out of action. Salvo Equations define this as the number of hits that can be absorbed before the Combat Power is reduced to zero, where Combat Power is defined as striking power minus the target's defensive power. For H3 ANW, this begins with the calculated damage points for each vessel as displayed in Figure 2, augmented by various modifiers to enhance or detract from this value. An example of one of these modifiers is seen in Figure 6.

ARMOR EFFECTS

Armor Rating	Bombs Penetrating	Gun Penetration (AP)	Gun Penetration (HE)	Missile Penetration
Light	GP	76 - 120 mm	76 - 130 mm	Fragments
Medium	SAP	121 - 140 mm	131 - 275 mm	0 - 25 DPs
Heavy	AP/HEAT	141 - 190 mm	276 - 406 mm	26 - 99 DPs
Special	Special AP	191 - 406 mm	--	100+ DPs

The armor penetration ratings for each gun in Annex C1 is for short range. At long range reduce the rating by one. Thus, a 203 mm gun firing HE shells can penetrate medium armor at short range but only light armor at long range.

Figure 6. Harpoon3 (ANW) Armor Effects Table

It is important to remember that just as with the Salvo Equations, a ship put out of action does not necessarily mean it is sunk; rather, it means it is either a neutralized threat or a firepower kill. H3 ANW provides Battle Damage Assessment (BDA) either through preset conditions, or user interface. It also takes into consideration the ability for shipboard repairs made by onboard personnel. Figure 7 displays some of the calculations used in affecting onboard repairs applicable to prolonged engagements.

BREAKDOWN REPAIR TABLE

	Time Since			
Breakdown (hrs)	6	12	24	48
Western Crew:	30%	35%	40%	45%
Russian Crew:	20%	25%	25%	25%
Third-World Crew:	10%	15%	15%	15%

Figure 7. Breakdown Repair Table Showing Repair Times and Percentages

The hits required to put a ship out of action linearly diminish her fighting strength. Staying power is dependent on the type of weapon, meaning the staying power of each ship is different against each type of weapon. Additionally, in real engagements, where a platform is hit is as important as with what. H3 ANW provides for tracking critical hits or hits that cause greater damage based on proximity to vital locations, as seen in Figure 8.

CRITICAL HIT TYPES

Die Roll	Surface Combatants	Aviation Ships	Merchants and Auxiliaries	Submarines (all weapons)	Torpedoes vs Surface Ships	Airburst & Fragm. Hits
1	Weapon Mount	Wpn Mount	Wpn Mount	Wpn Mount	Weapon Mount	Sensor
2	Weapon Mount	Flight Deck	Cargo	Pressure Hull	Flooding	Sensor
3	Weapon Mount	Hangar	Cargo	Sensor	Flooding	Sensor
4	Sensor	Hangar	Flooding	Flooding	Flooding	Weapon
5	Sensor	Sensor	Flooding	Flooding	Flooding	Weapon
6	Flooding	Flooding	Fire	Flooding	Sonar	Wpn/Flt Deck
7	Fire	Fire	Fire	Fire	Engineering	Wpn/Flt Deck
8	Engineering	Engineering	Engineering	Engineering	Engineering	Wpn/Flt Deck
9	Bridge/CIC	Bridge/CIC	Bridge/CIC	Bridge/CIC	Engineering	Flight Deck
10	Rudder	Rudder	Rudder	Rudder	Rudder	Bridge/CIC

Figure 8. Harpoon3 (ANW) Critical Hit Types Table

4. Scouting Effectiveness

Scouting effectiveness is the degradation of striking power measured in hits per salvo, caused by imperfect detection or tracking of enemy targets. It can be described as the level of efficiency regarding the collection of enemy target information for a successful attack.

TMA SOLUTION QUALITY TABLE

Range Band	Target Range (nm)	Good Solution	Fair Solution	Poor Solution	BOL Solution
Short	0-2.5	30%/Turn	40%/Turn	50%/Turn	Detection
Medium	2.6-5.0	20%/Turn	30%/Turn	40%/Turn	50%/Turn
Long	5.1-10.0	10%/Turn	20%/Turn	30%/Turn	40%/Turn
Very Long	10.1-20.0	5%/Turn	15%/Turn	25%/Turn	35%/Turn

TMA Solution Modifiers	Short/Medium/Long	Very Long
Passive Sonar	+20%	+10%
Passive Ranging Sonar	+40%	+20%
Active Sonar	+50%	+50%
Periscope	+30%	+15%
Laser/Radar Range Finder	+60%	+60%
Changes Course (20+°)	-25%	-25%
Changes Speed (5+ knots)	-25%	-25%

Figure 9. TMA Solution Quality Table

In H3 ANW, as with Striking Power, several modifiers are used to affect the outcome of Scouting Effectiveness. These include equipment capabilities within specific environments as seen in Figure 9, visual line-of-sight (LOS) tables as displayed in Figure 10, and tables for various sensors affected by environmental factors, see Figure 11. Further degradation can be caused by the aspect and nature of the target, e.g., small and hiding within clutter such as other boats, land, etc., with a platform aspect that reduces the RCS, see Figure 12.

VISUAL LINE OF SIGHT

Height (m)	Height (ft)	Observing Unit Class	Distance in nautical miles Large	Med	Small	Periscope
25	82	**Large**	20	17	16	2
14	46	**Medium**	17	15	13	2
8	26	**Small**	16	13	11	2
.2	.5	**Periscope**	11	8	6	1

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AIR-TO-SURFACE SIGHTING

Distance in nautical miles

Large	Medium	Small	Periscope
25	19	14	3

Figure 10. Visual Line of Sight Table

VISIBILITY VARIATION TABLE

(variation in nautical miles)

Sigma (nm)	D10 Roll 1	2	3	4	5	6	7	8	9	10
4	-4	-3	-2	-1	0	1	1.5	2	3	4
3	-3	-2	-1	-.5	0	0	.5	1	2	3
2	-2	-1.5	-1	0	0	0	.5	1	1.5	2
1.5	-1	-1	-.5	0	0	0	0	.5	1	1.5
1	-1	-1	-.5	0	0	0	0	.5	.5	1
.5	-.5	-.5	-.5	0	0	0	0	.5	.5	.5

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INFRARED SENSOR RANGES

IR Sensor Generation	Stealthy	Small & Med Ships/Subsonic Aircr. or Msl	Lge Ship or Aircr./ Supersonic Aircr. or Missile
1	1 nm	2 nm	4 nm
2	2 nm	5 nm	7 nm
3	3 nm	8 nm	10 nm
4	4 nm	10 nm	12 nm

IR ranges are reduced by water in the air. The more moisture, the shorter the range.

Precipitation	% Degradation
Drizzle - Light Rain or Fog	50%
Intermediate Rain or Fog	75%
Heavy Rain or Fog	100%

Figure 11. Infrared Sensor Ranges

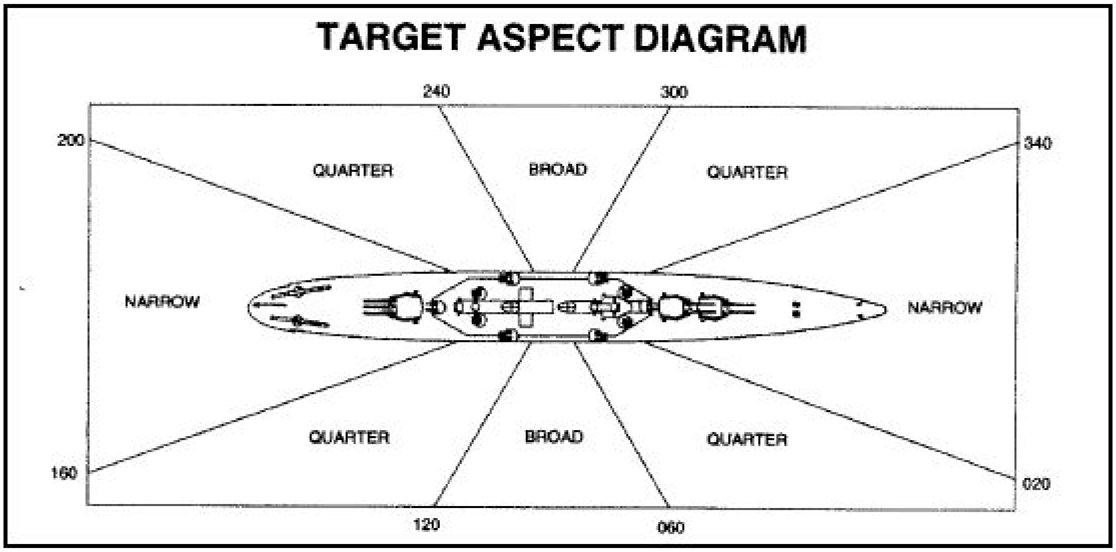


Figure 12. Target Aspect Diagram

5. Defensive Readiness

Defensive readiness is the extent to which a target ship fails to take defensive actions up to her designed combat potential. This may be due to unpreparedness, lack of a condition of readiness, or reduced readiness caused by enemy Emission Control (EMCON) efforts.

H3 ANW uses modifiers for Pilot Experience, but no similar modifier that pertains to surface or subsurface vessels. However, certain vessel and equipment characteristics do affect readiness in regards to EMCON. Figure 13 displays how H3 ANW tabulates Radar LOS, while Figure 14 shows the Low RCS modifier table.

RADAR LINE OF SIGHT TABLE (Ranges in nm)

Height (m)	Height (ft)	Obsv. Unit	Aircraft Altitudes VHigh	High	Med	Low	VLow	Horizon	Ships Large	Med	Small
24700	81036	VHigh	700	582	446	389	362	350	364	362	360
10800	35433	High	582	463	327	271	244	232	246	244	241
1850	6069	Med	446	327	192	135	108	96	110	108	106
310	1017	Low	389	271	135	78	51	39	53	51	49
30	98	VLow	362	244	108	51	24	12	26	24	22
0	0	Horizon	350	232	96	39	12	0	14	12	10
40	131	Large	364	246	110	53	26	14	28	26	24
29	95	Med	362	244	108	51	24	12	26	24	22
19	62	Small	360	241	106	49	22	10	24	22	19

Figure 13. Radar Line of Sight Table

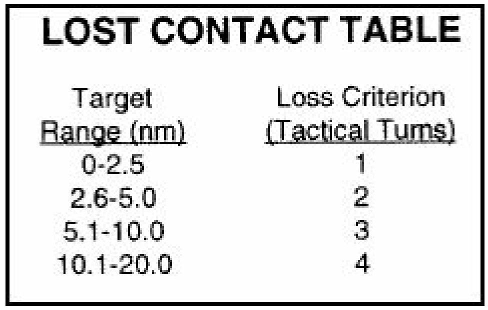
LOW RCS MODIFIER TABLE

Missile Generation	VSmall RCS	Stealthy RCS
1	+1.0	+2.0
2	+1.0	+2.0
3	+1.0	+2.0
4	+0.5	+1.5

Figure 14. Low RCS Modifier Table

6. Training Effectiveness

Training effectiveness is the degree to which a firing or targeting ship does not reach her designed combat potential due to inadequate training, organization, or motivation. Once again, H3 ANW does not have any built-in method of determining the training effectiveness of a vessel’s crew; but rather relies on the guidance and direction of the user interface. While many actions can be assigned to automated responses, the experience of the user allows for actions that enhance the probabilities for detection, kill, etc. All of this in accordance with set parameters such as the Lost Contact Table in Figure 15.



LOST CONTACT TABLE

Target Range (nm)	Loss Criterion (Tactical Turns)
0-2.5	1
2.6-5.0	2
5.1-10.0	3
10.1-20.0	4

Figure 15. Lost Contact Table

7. Seduction Countermeasures Effectiveness

Seduction countermeasures effectiveness is defined as the level of success in causing incoming weapons to miss. When an incoming weapon is homing onto a ship, the seduction phenomenon diverts the weapon away from the ship. Seduction soft kill is a major complementary element to conventional hard kill defense, i.e., SAMs. Furthermore, the effectiveness of seduction countermeasures is improved when the RCS of the targeted ship is reduced, increasing the probability that a homing weapon will change course and engage the non-existent target.

Along with tabulated vessel characteristics, such as RCS (see Figure 14) and Armor Effects (see Figure 6), H3 ANW also uses modifiers for such dynamic actions as seeker acquisition cones and the probability for a seeker lock-on (Figure 16), and the jammer effectiveness of a platform (Figure 17). Tracking the interaction of these tables allows for a more complete and realistic combat engagement based upon modern real-world technology and tactics.

SEEKER ACQUISITION CONES

Seeker Type	Bearing Limits	Ship Target Size: Large, Med, Small	Ship Target Size: VSmall Stealthy
Radar/1st	±15°	5 nm	2.5 nm
Radar/2nd	±30°	7 nm	3.5 nm
Radar/3rd	±45°	10 nm	5.0 nm
Non-radar/1st	±30°	5 nm	2.5 nm
Non-radar/2nd	±45°	7 nm	3.5 nm

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SEEKER LOCK-ON CHANCE TABLE

Size Class	Chance of Lock-on
Large	16
Medium	8
Small	4
Very Small	2
Stealthy	1

Figure 16. Seeker Acquisition Cones and Lock-on Chance Tables

JAMMER EFFECTIVENESS TABLE

Radar System	Main Beam Range Modifier	Sidelobe Range Modifier
Phased Array	0.75	0.90
Regular	0.25	0.60

Figure 17. Platform Jammer Effectiveness Table

8. Distraction Countermeasures Effectiveness

Distraction countermeasures effectiveness is the ability for a defensive platform to cause enemy shots to miss before employment of the defensive power. The purpose of distraction is similar to the seduction phenomenon; however, the timing is different. Distraction happens preferably before the enemy fires its weapons or prior to weapon lock-on. H3 ANW uses a combination of tables to coordinate how the characteristics of various platforms interact to provide distraction.

D. INTRODUCTION OF LEAKERS

Previous thesis work introduced leakers through modified Salvo Equations in order to better represent real scenarios. H3 ANW, while not defining them as leakers, still allows for varying percentages of missiles to evade functioning defenses based upon the interaction of platform, weapons, and environmental effects.

E. MEASURE OF EFFECTIVENESS

The main Measure of Effectiveness (MOE) used in H3 ANW is the achievement of scenario specific Victory Conditions (VC). These conditions for victory can include achieving a percentage of enemy forces, instillations or platforms destroyed; reaching a specified navigation point (NAVPOINT); maintaining a specific percentage of friendly forces in operational condition; or a number of other user defined conditions. The scenario editor allows the designer to select what victory conditions are used in an engagement. The victory conditions designed for this thesis are complete destruction of all opponent platforms.

F. MODEL IMPLEMENTATION

A scenario designed to emulate the thesis work of LTJG Ozdemir's use of the embellished Salvo Equations Model has been designed in H3 ANW. Variations on the execution and action of forces were used to compare outcomes between the collected Ozdemir (2009) data and the dynamic interactions of the detailed game data available in H3 ANW as displayed in Figure 18.

ANTISHIP MISSILE ATTACK TABLE

Large Target Signature

ECM Gen	Missile Gen	Missile Ph	Jamming	Decoy	Jamming & Decoy
1	1	0.75	0.74	0.72	0.71
	2	0.80	0.85	0.78	0.85
	3	0.85	0.90	0.85	0.90
2	1	0.75	0.72	0.70	0.68
	2	0.80	0.79	0.77	0.76
	3	0.85	0.85	0.82	0.82
3	1	0.75	0.71	0.67	0.64
	2	0.80	0.77	0.75	0.72
	3	0.85	0.84	0.82	0.81
4	1	0.75	0.67	0.59	0.52
	2	0.80	0.74	0.69	0.64
	3	0.85	0.81	0.77	0.73

Very Small Target Signature

ECM Gen	Missile Gen	Missile Ph	Jamming	Decoy	Jamming & Decoy
1	1	0.75	0.55	0.36	0.26
	2	0.80	0.85	0.38	0.80
	3	0.85	0.90	0.56	0.85
2	1	0.75	0.53	0.32	0.23
	2	0.80	0.62	0.43	0.33
	3	0.85	0.69	0.53	0.42
3	1	0.75	0.51	0.27	0.19
	2	0.80	0.58	0.37	0.27
	3	0.85	0.65	0.44	0.34
4	1	0.75	0.49	0.23	0.15
	2	0.80	0.56	0.32	0.22
	3	0.85	0.62	0.39	0.29

Medium Target Signature

ECM Gen	Missile Gen	Missile Ph	Jamming	Decoy	Jamming & Decoy
1	1	0.75	0.67	0.59	0.52
	2	0.80	0.85	0.72	0.80
	3	0.85	0.90	0.80	0.85
2	1	0.75	0.64	0.53	0.45
	2	0.80	0.71	0.62	0.55
	3	0.85	0.79	0.72	0.67
3	1	0.75	0.61	0.46	0.37
	2	0.80	0.68	0.56	0.48
	3	0.85	0.75	0.65	0.57
4	1	0.75	0.57	0.39	0.30
	2	0.80	0.62	0.45	0.35
	3	0.85	0.68	0.51	0.41

Stealthy Target Signature

ECM Gen	Missile Gen	Missile Ph	Jamming	Decoy	Jamming & Decoy
1	1	0.75	0.53	0.32	0.23
	2	0.80	0.85	0.34	0.80
	3	0.85	0.90	0.40	0.85
2	1	0.75	0.51	0.27	0.19
	2	0.80	0.58	0.37	0.27
	3	0.85	0.65	0.44	0.34
3	1	0.75	0.49	0.23	0.15
	2	0.80	0.56	0.32	0.22
	3	0.85	0.62	0.39	0.29
4	1	0.75	0.47	0.18	0.11
	2	0.80	0.52	0.24	0.16
	3	0.85	0.58	0.31	0.21

Small Target Signature

ECM Gen	Missile Gen	Missile Ph	Jamming	Decoy	Jamming & Decoy
1	1	0.75	0.61	0.46	0.37
	2	0.80	0.85	0.56	0.80
	3	0.85	0.90	0.64	0.85
2	1	0.75	0.55	0.36	0.26
	2	0.80	0.65	0.49	0.40
	3	0.85	0.72	0.60	0.51
3	1	0.75	0.53	0.32	0.23
	2	0.80	0.62	0.43	0.33
	3	0.85	0.69	0.53	0.42
4	1	0.75	0.51	0.27	0.19
	2	0.80	0.58	0.37	0.27
	3	0.85	0.65	0.44	0.34

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ANTI-SHIP MISSILE

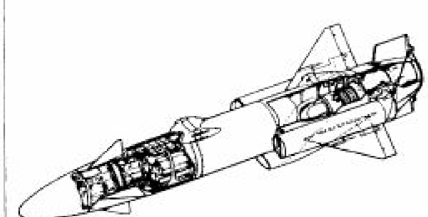

Figure 18. Anti-ship Missile Attack Table

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IV. SCENARIO PARTICIPANTS

A. FRIENDLY FORCE SCENARIO

The scenario for this thesis is an encounter of Friendly Forces (FRIFOR) and Opposition Forces (OPFPR) in the Strait of Hormuz. This littoral environment is a surrogate to many other regions, nations, and area of operations for non-state actors and military organizations around the world. The scenario’s outcome is to depict littoral warfare operations in a confined area consisting of numerous islands and bays that provide havens for small boat operations. These tactics have proven deadly for many conventional ships. Navies around the world are adapting to this environment and are adopting smaller, lighter, cheaper, and stealthier ships with greater capability to overcome these asymmetric multi-axis threats.

As opposed to destroyers or cruisers, the LCS, with numerous air assets and lower heat and radar signatures, is considered a platform capable of providing an answer to these threats (CRS Report, 2008). Previous theses have analyzed whether or not LCS is the best design for this environment, or could another ship provide similar or better performance at less cost (Ozdemir, 2009)? This thesis uses the off-the-shelf simulation software Harpoon3 Advanced Naval Warfare (H3 ANW) to emulate and enhance some of the results produced from a scenario that considered the LCS, and a similar Russian design, the RS Steregushchiy Class (Project 20380) Frigate. This scenario places a FRIFOR LCS squadron within the Strait of Hormuz in support of CSG-ESG operations in the Persian Gulf. Iran announces the closure of the Strait to all commercial traffic in response to a perceived threat from Israel. Hostilities commence when the United States and allies challenge the closure. Concurrent allied operations have eliminated the Iranian Air Force, shore-based SSM, and mine threats. What remains at the scenario start is a robust Iranian littoral threat capable of devastating commercial traffic.

Five types of Iranian naval vessels are considered, with each capable of carrying missiles or torpedoes. There are two classes of submarines that carry torpedoes, one conventional and one midget; two classes of missile carrying Fast Patrol Boats (FPBs); and one class of fast missile boat. With the exception of submarines, all OPFOR assets are very fast. Larger classes of ships are either obsolete or assumed to have been previously destroyed. Non-missile or torpedo-carrying boats are not applicable to the analysis, since they present no lethal threat.

FRIFOR ships are composed of an LCS Surface Action Group (SAG). To form a squadron level Task Force, the SAG will be reinforced by other LCSs. This Task Force will be positioned inside the Strait in the vicinity of the strategic Iranian naval bases. They will be ready to neutralize adversarial Iranian ships that are intent upon attacking traffic transiting through the Strait. The shipping lanes, however, are shifted further south, just off the territorial water lines of Oman and U.A.E. This is to reduce the attackers target acquisition range. FRIFOR ships operate inside a buffer zone between Iranian bases and the shipping lanes.

Initially, the FRIFOR squadron will be comprised of LCS only. After this engagement is modeled, the Steregushchiy Class frigates will replace the LCS in the model. The scenario results for each FRIFOR platform are then compared and evaluated.

B. FRIENDLY FORCE CANDIDATES

For model simplification, each LCS is assumed to use two MH-60R Seahawk helicopters, while Steregushchiy uses one KA-27 Helix helicopter; allowing the analysis to be focused on the ships and aircraft combination. Detailed information on FRIFOR platform designs has been compiled from the websites of *Jane's Fighting Ships* (2009) and *Naval Technology* (2009) and is in Appendix A. Model Assumptions are in the next chapter. The following two tables represent general characteristics and weapon capabilities of the FRIFOR platform designs. It is assumed that all ships have organic ASW capabilities.

Class	**Year**	**Length**	**Draft**	**Weight**	**Speed**	**Crew**
Freedom	2008	115.3 m.	3.9 m.	3089 t.	45 Kts.	50
Steregushchiy	2007	104.5 m.	3.7 m.	2200 t.	26 Kts.	100

Table 3. General Ship Design Characteristics

Class	**SSM**	**SAM**	**PDMS**	**Gun**	**CIWS**	**Torpedo**
Freedom	-	-	21	57 mm.	-	-
Steregushchiy	-	-	8	100 mm.	4	8

Table 4. Ship Weapons Capabilities

1. Freedom Class LCS

The first candidate for the Task Force is the USS Freedom. Since the tri-hull USS Independence has essentially the same capabilities as USS Freedom, it is not considered as a separate alternative. Freedom is a medium size frigate, with significant stealth features for littoral warfare operations. The main characteristics of the ship include tailored mission packages to be carried based on the required mission. Depending on the mission package, two organic aircraft embarkation schemes are available: two MH-60R Seahawk helicopters, or one MH-60R Seahawk and three MQ-8B Fire Scout UAVs.

LCS has no onboard weapon systems and must rely on mission package component weapons for striking power; Seahawk helicopters carrying AGM-114 Hellfire missiles in ASUW role and Seahawk helicopters carrying Mk-54 torpedoes in ASW role. SAM capability is limited to RAM (Rolling Airframe Missile) Point Defense Missile System (PDMS).

2. Steregushchiy Class Frigate (Russian LCS)

Also known as the Russian LCS, Steregushchiy, although built for the same purpose, differs from the LCS in design and operational responsibilities. Built as part of the traditional Russian fleet, where every ship has a different specific duty, Steregushchiy is not quite as independent a player as LCS. For analytic purposes however, she is considered a candidate as a new ship with a goal towards littoral warfare operations. Steregushchiy lacks SSMs, but does have torpedo launchers as well as one Helix ASW helicopter.

C. OPPOSING FORCE THREAT ASSESSMENT AND ASSUMPTIONS

According to worldwide intelligence centers, the navy is Iran’s most strategically important military service (Jane’s Sentinel Security Assessment, 2009). The Iranian navy is rebuilding and modernizing itself along with Iran’s other programs focusing on nuclear weapons and long-range ballistic missile building efforts. As most of Iran’s oil exports and trade pass through the Strait of Hormuz, the vital importance of the Persian Gulf is an obvious reason for its modernization efforts after the Iran-Iraq war (Ripley, 2008). Iran’s technology transfer from China, North Korea and Russia is well known. In addition, its indigenous shipbuilding efforts have, in recent years, proven fruitful (Fish, 2008; Gelfland, 2008).

Along with Iran’s efforts towards building long-range ballistic missiles, anti-ship missiles based on Chinese technology pose a significant threat in the Persian Gulf. The Chinese C-802 missile is claimed to be a reverse-engineered Exocet missile (Federation of American Scientists, 2009; Global Security.Org, 2009). They have been put into service as upgrades to their navy’s aged and unmaintained Harpoon missiles. The missiles have also been placed onto the new fast missile boats. Besides the C-802, short-range Chinese C-701 SSMs are also re-engineered in Iran. These are becoming the main assault weapons of the newly built fast (50 knots or over) and small boats (Jane’s Fighting Ships, 2009).

The new Iranian small boats, with almost no RCS and very high speeds, pose a significant threat to FRIFOR operating close to Iranian shores. Although these boats do not carry long-range SSMs, their local knowledge of the waters and high-speed capabilities give them the advantage to deliver their short-range SSMs. As mentioned, some of these boats are not missile-capable, but are torpedo-capable. Although Iran's capability to deliver a torpedo strike is uncertain, the effect of a torpedo hit due to its heavy warhead makes it a serious threat. The fact that some of these boats are semi-submersible increases the possibility of OPFOR boats approaching to closer distances undetected. It is important to note that this thesis does not model all of the forces briefed here, but tailors the OPFOR to specific platforms.

1. Iranian Naval Force Review

Table 5 outlines the Iranian Navy OPFOR surface and sub-surface capability. Large naval assets, such as frigates, corvettes, amphibious ships, auxiliary ships and other obsolete ships are excluded. Naval air assets and small inshore boats with no missile or torpedo capability are also excluded. It is an assumption either that the Iranian Navy's obsolete assets will pose minimal threat or that the bigger ships will have already been taken out in previous operations or aircraft strikes. The remaining forces from the Iranian Navy include submarines and the smaller, newer and faster boats with lethal weapons. Iranian Caspian Fleet vessels are also not considered. After careful consideration of the strength of the Iranian Navy based on the latest intelligence from open sources, it is assumed that the Iranian Navy's lethal combatant strength is within the following classes and numbers shown in Table 5. Detailed information regarding each class is compiled from the websites of *Jane's Fighting Ships* (2009), *Federation of American Scientists* (2009) and *Global Security.Org* (2009) and displayed in later sections and in Appendix B.

Submarines (Subs) **SSK/SSC**	**Fast Patrol Boats (FPBs)** **PGFG**	**Small Missile Boats** **PTG**	**Small Torpedo Boats** **PTF**
3 x Kilo	10 x Kaman	10 x Mk 13	10 x Tir
5 x Yono	10 x Thondor	5 x C-14	15 x Peykaap I
		25 x Peykaap II	3 x Kajami
			3 x Gahjae

Table 5. Iranian Naval Forces Strength

2. Iranian Naval Bases

Iran has numerous operational naval bases that control the entire Persian Gulf, Strait of Hormuz, and Gulf of Oman. After careful consideration of the open source intelligence concerning Iranian naval bases, their locations, operational status, and Google Earth imagery, it is deduced that Iran has the operational naval bases shown in Table 6 (Jane's World Navies, 2009; Jane's Fighting Ships, 2009; Global Security.Org, 2009; Military Net, 2009).

Very Large Naval Bases	**Large Naval Bases**	**Medium Naval Bases**	**Small (Island) Naval Bases**
Bandar Abbas*	Bandar Lengeh*	Qeshm Island*	Larak Island*
Bushehr	Bandar Beheshti	Jask**	Abu Musa Island*
	Bandar Khomeini	Kharg Island	Sirri Island**
		Khorramshahr	

Table 6. Iranian Naval Bases

* These naval bases are located inside the Strait of Hormuz

** These naval bases are located just outside of the Strait

Bandar Abbas is the largest and most strategically-located naval base in Iran. It is on the mainland north of the Strait of Hormuz, approximately 30 NM from the shipping lane center. It is the headquarters of the Iranian Navy and responsible for the 1st Naval District. A major portion of Iranian shipbuilding facilities and dockyards are located here as well as many major naval assets. Kilo class submarines previously stationed here have recently moved to Bandar Beheshti for better access to open ocean. The second largest base is Bushehr. It is located on the mainland in the middle of the Persian Gulf and is responsible for the 2nd Naval District.

Another large base is Bandar Lengeh, which controls the Persian Gulf entrance of the Strait. Previously mentioned, Bandar Beheshti is the newly designated submarine base in the Gulf of Oman. Bandar Khomeini is located in the oil-rich Basra region.

Of the medium sized bases, the most important is Qeshm Island, which is strategically located inside the Strait of Hormuz. It is an island practically connected to the mainland forming an extension deep into the Strait. Jask is the newest naval base on the Gulf of Oman entrance to the Strait and it is built to better control shipping lanes. Kharg Island is an island base located in a major offshore oil region in the central Persian Gulf. Lastly, Khorramshahr, located in the Basra region, is located on the border of Iraq.

The three small island bases are typical piers designed to support small naval assets. Larak Island is in the Strait’s heart and Abu Musa Island, although disputed by the United Arab Emirates (UAE), is in the western entrance to the Strait. Sirri Island is just outside the Strait and further west than the previous two islands.

3. Iranian Naval Base Asset Allocation

Considering the Iranian oil drilling and processing sites, major trade routes, geopolitically important strategic locations, such as the Strait of Hormuz, the ongoing United States and coalition exercises and operations in and outside of the Persian Gulf, it is assumed that the strength of the Iranian Navy is distributed as depicted in Table 7. This assumption is made regarding current locations of the Iranian Naval assets, excluding the Caspian Fleet, and has been investigated using open source intelligence. This assumption is for analytical purposes only.

Naval Base	**Submarines**	**PGFG**	**PTG**	**PTF**
Bandar Abbas	2xKilo 3xYono	6xKaman	2xPeykaap II	
Bushehr	2xYono	4xKaman	2xPeykaap II	
Bandar Lengeh		4xThondor	3xC-14 3xPeykaap II	
Bandar Beheshti	1xKilo	4xThondor	2xMk 13 2xPeykaap II	
Bandar Khomeini		2xThondor	2xMk 13 2xPeykaap II	
Qeshm Island			2xMk 13 2xC-14 2xPeykaap II	2xTir 3xPeykaap I
Jask			2xMk 13 2xPeykaap II	2xPeykaap I
Kharg Island			2xMk 13 2xPeykaap II	2xTir 2xPeykaap I
Khorramshahr			2xPeykaap II	2xPeykaap I
Larak Island			2xPeykaap II	2xTir 2xPeykaap I 2xKajami
Abu Musa Island			2xPeykaap II	2xTir 2xPeykaap I 1xKajami 1xGahjae
Sirri Island			2xPeykaap II	2xTir 2xPeykaap I 2xGahjae

Table 7. Iranian Naval Base Asset Allocation

D. OPPOSING FORCE SCENARIO

In this section, the OPFOR operational plans and FRIFOR Scenario merge and create the modeled scenario. There are a total of seven Iranian bases in and around the Strait of Hormuz. (See Figure 19) The total number of assets allocated to these bases is 33 vessels.

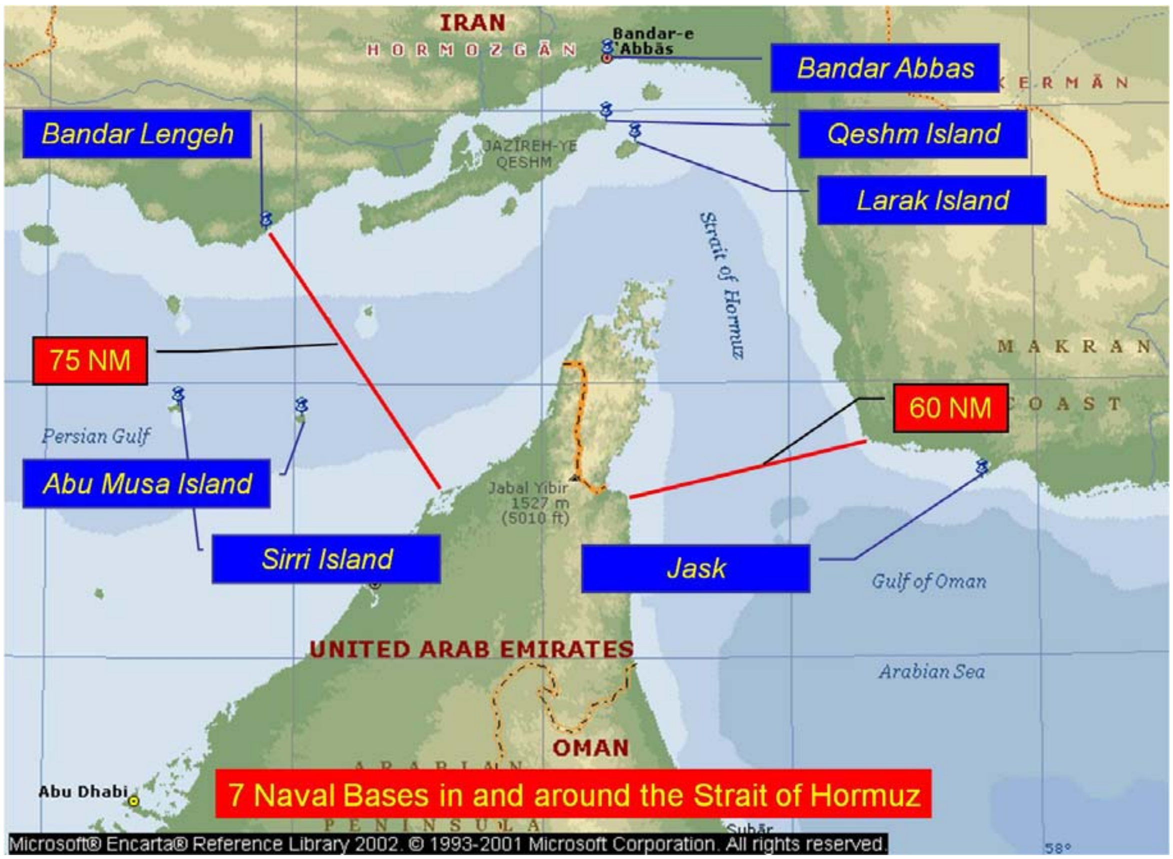

Figure 19. Strait of Hormuz and Vicinity, after Microsoft Encarta (Best Viewed in Color)

To focus the scenario and the model into a higher resolution geographic area, four bases, Sirri Island, Abu Masu Island, Larak Island and Jask, have been omitted from the OPFOR scenario. This is due to the types of platforms available and the objective of modeling the scenario with Harpoon3 (ANW). As a result, only three bases (Bandar Abbas, Qeshm Island, and Bandar Lengeh) with a total number of 20 allocated assets are considered. The first two bases are located in the central Strait; the third is on the west side, as depicted in Figure 20. Additionally, the Pakkaap, Mk-13, and PTF platforms were removed from the model in order to provide a focused OPFOR within the H3 ANW model.

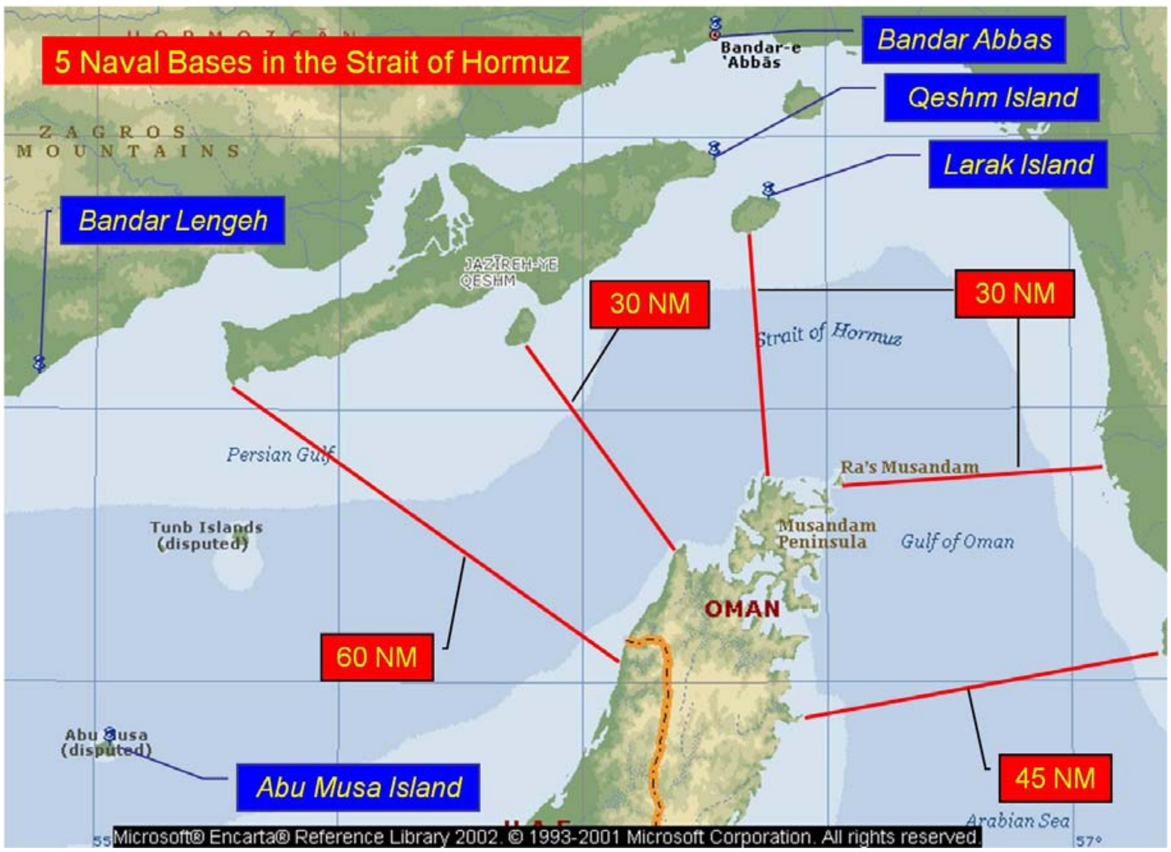

Figure 20. Scenario Naval Bases in Strait of Hormuz, after Microsoft Encarta (Best Viewed in Color)

Considering base locations, Iranian Naval Forces are divided into two groups and threat to FRIFOR is expected from two different axes: the Central Strait area with two bases (13 Iranian naval assets) and the Western Strait area with one base (seven assets). Considering the geographical separation, simultaneous engagements are assumed to occur in two different places. The FRIFOR Squadron is also divided into two groups. This allows for an encounter with two OPFOR groups consisting of the Iranian assets listed in Table 8.

The engagements are to take place in the following order. The first attackers from Iranian bases will be the Kilo submarines. When hostilities start, the Kilo Class submarines are expected to be in central part of the Strait ready to sink any tanker, merchant, or enemy naval vessel within weapon range. The second wave of attackers are the FPBs with C-802 long-range SSMs.

The third wave is the Yono Class midget submarines. Because of their small size and shore support dependence, they are not expected in open seas, but do pose a threat in the Strait. The final attacker wave contains the PTGs with short range SSMs restricted to the near shore zone.

Naval Base	**Submarines**	**PGFG**	**PTG**
Bandar Abbas	2xKilo 3xYono	6xKaman	
Bandar Lengeh		4xThondor	3xC-14
Qeshm Island			2xC-14

Table 8. Iranian Naval Base Asset Allocation for Scenario

Summarizing, there are two engagement regions and a total of four waves of attackers. Referencing the thesis work of LTJG Ozdemir, the Salvo Model reveals the number of FRIFOR ships needed for Breakpoint and Dominance for each encounter given the number of OPFOR. Therefore, FRIFOR is divided into two squadrons and the force sizes become model variables. The OPFOR is assumed to be structured into the following Task Force (TF) and Task Groups (TG). TF 480, composed of four TGs and a total of 13 vessels, operates out of Bandar Abbas and Qeshm Island. TF 490, composed of 2 TGs and a total of 7 ships, operates out of Bandar Lengeh, see Table 9.

TF 480	**Units**	**TF 490**	**Units**
TG 480.01	***SSK*** 2 X Kilo	***TG 490.01***	***PGFG*** 4 x Thondor
TG 480.02	***PGFG*** 6 x Kaman	***TG 490.02***	***PTG*** 3 x C-14
TG 480.03	***SSC*** 3 x Yono		
TG 480.04	***PTG*** 2 x C-14		

Table 9. OPFOR Order of Battle

E. OPPOSING FORCE ASSETS

Detailed information on each class of OPFOR platform and their weapons capability is in Appendix B.

1. Kilo (Project 877 EKM) Class Submarine (SSK)

The Iranian Navy has three Russian-built Kilo-class conventional submarines. Although it is reported that these submarines underwent major refit under Russia’s supervision, including the addition of Russian ASCMs, this update is not confirmed and was not modeled. (Jane’s Underwater Warfare Systems, 2009) A typical diesel submarine, Kilo-class carries 18 heavyweight (533 mm) torpedoes. The submarines’ mine-laying capability is not considered in the model. Reports of their transfer to a base in the Gulf of Oman have been confirmed, but for the sake of this analysis, two Kilo class boats operate out of Bandar Abbas, as previously stated.

2. Yono (IS 120) Class Coastal Submarine (SSC)

Based on North Korean midget submarine technology, the recently built five Yono class boats are very small and shore-support dependent. They are designed for littoral waters, and can deliver at least two torpedoes. They are considered to be built as covert weapons to strike vessels in the Strait of Hormuz (Jane’s Underwater Warfare Systems, 2009). Three Yono class subs are used in this scenario.

3. Kaman (Combattante II) Class FPB (PGFG)

Built in late 1970s and early 1980s in France and recently in Iran, these 13 ships are the primary missile force within the Iranian Navy for territorial water defense. Having had their weapons upgraded to four C-802s, they pose a serious threat to any vessel operating in or around the Strait of Hormuz. Six Kaman class FPBs are used in this scenario.

4. Thondor (Houdong) Class FPB (PGFG)

Ten Thondor class FPBs were built by China in 1990s and, along with Kaman class FPBs, form the long-range SSM capable force of the Iranian Navy. Armed with four C-802s, they are another formidable threat facing FRIFOR. Four Kaman class FPBs are used in this scenario.

5. C-14 Class Patrol Boat (PTG)

Chinese built, C-14s carry four C-701 short-range anti-ship missiles, based on Chinese FL-10 technology, and are designed for coastal defense. Nine were delivered in the early 2000s; five missile-capable and the rest designed as inshore craft. PTGs have speeds of 50 knots or over, weight of 30 tons or less and length of 21 meters. Five missile-capable C-14 class PTGs are used in this scenario.

V. ANALYSIS AND RESULTS

A. FRIENDLY FORCE MODEL ASSUMPTIONS AND LIMITATIONS

This section outlines the assumptions and limitations of the FRIFOR platforms considered in the model. To determine model parameters, certain assumptions had to be made to allow for ship capability comparisons. The helicopters used by the LCS platform are MH-60R Seahawks, with either an anti-submarine warfare (ASW) weapons loadout of two Mk-54 torpedoes or an anti-surface warfare (ASUW) weapons loadout of eight Hellfire missiles. Due to their limited size, capacity, and smaller flight deck, Steregushchiy platforms carry the lighter weight KA-27 Helix with an ASW loadout of one torpedo. Against PGFGs and PTGs, helicopter-launched Hellfires are used as the primary means of engagement. It is assumed that using Harpoon-like ship-launched long-range SSMs against small boats is not reasonable due to cost and target-allocation schemes.

For Salvo Equation modeling purposes, the Hellfire missiles fired from FRIFOR helicopters and the C-701s fired from PTGs are considered equivalent weapons. Similarly, the FRIFOR long-range SSMs (Harpoon, Exocet or RBS) are considered to be equivalent with Iranian C-802s. In the ship versus submarine encounters all the torpedoes (ship, helicopter or submarine-launched) are also considered equivalent. Harpoon3 Advanced Naval Warfare (H3 ANW) however, has the ability to keep track of each weapon type and its probability of success under varying environmental and combat conditions. Given this capability, the previous Salvo Equation assumption of homogeneity was not required.

During encounters, the offensive weapons used by the opposing sides are not necessarily of the same equivalency. For example, LCS platforms use helicopter-launched Hellfires as their primary weapon against all enemy surface ships; however, the PGFGs and PTGs return fire on LCS with C-802s and C-701s respectively. Additionally, H3 ANW also allows combat interactions with large caliber guns, ultimately the biggest threat to helicopters.

For Hughes' Salvo Equation modeling purposes, the LCS unique mission package concept is not fully recognized. Against Iranian submarines, LCS has the ASW mission package employed, specifically two helicopters. When the threat changes to surface combatants, an ASUW mission package is employed, with either two helicopters or one helicopter and UAVs, depending on the threat, PTG or PGFG respectively. This transition is assumed to occur successfully after an encounter and between waves of OPFOR attackers. During the encounters where helicopters are employed, they are assumed in the air before the salvo exchange commences and refueled after each encounter. Also after each encounter, the ship and helicopter weapons are reloaded.

For H3 ANW modeling, again the specific tailored packages are not employed. Rather, a mix of capabilities are used to develop a more realistic scenario. Weapon loadouts for helicopters are tailored to the expected threat, explained in the greater detail below. Helicopters are designed to be ready to launch as soon as the platform approaches the threat zone or upon receiving indications and warning (IW). Additionally, when developing the scenario, the Editor displays a 1/3 Rule check box. When this is selected (default setting), H3 ANW will keep one-third of the assigned aircraft in the air. This applies to area missions only. If the 1/3 Rule check box is not selected, all of the aircraft assigned to the area mission are launched. The model then operates all platforms according to their individual characteristics as various modifiers apply. The model for this thesis used the 1/3 Rule to operate the scenario as close to a real-world platform as possible, controlling the launch and coordination of helicopter assets while keeping some in a ready status for emergent tasking. Fuel consumption during search patterns and weapon usage during engagements determine helicopter landing, refueling, and rearming requirements as opposed to between each wave of attackers as with the Salvo Equation model.

The successive wave of attackers concept worked well for calculations in the Salvo Equation model; however, it was not successfully employed in the H3 ANW model. Despite attempts to model OPFOR assets within their expected capabilities and range limits, their physical proximity within the Strait of Hormuz meant that many of their designed patrol zones overlapped as did many of their weapon range capabilities. This was not unexpected, and is believed to have produced a more realistic scenario, albeit not one conducive to making direct comparisons between the outcomes of the Salvo Equation model and the H3 ANW model.

1. Freedom Class LCS

In the Salvo Equation model, LCS engagements use two helicopters along with UAVs for scouting, but only helicopters are used for weapon-delivery. LCS has no ship-born striking power (SSMs or torpedoes). LCS operates two helicopters for ASW with a striking power of four torpedoes or two helicopters for ASUW, against PTGs with a striking power of 16 Hellfires. Against the PGFGs, it is assumed that LCS should operate only one helicopter with striking power of 8 Hellfires. LCS defensive power is nine against the SSMs. This is based upon a sum of 21 cell RAM launcher and a capable rapid-firing 57 mm gun. Staying power against lightweight torpedoes and long-range SSMs is 1.9 and short-range SSMs is 2.9 due to differences in warhead sizes. More extensive staying and defensive power explanations of FRIFOR ships are in Appendix C of Ozdemir (2009).

In the H3 ANW model, the two MH-60s for each platform are armed according to intelligence regarding expected OPFOR capability. TF01, which approaches from the East into the Strait of Hormuz, is given IW that the Iranian Kilo subs are stalking targets near the mouth of the strait, while the Yono midget subs are limited in endurance and are in closer proximity to shore support from the base at Qeshm. This allows each LCS platform in TF01 to employ one MH-60R for ASW prosecution and one MH-60R in an ASUW patrol mission. This tasking was not consistent with LCS initial module loadout, but demonstrates how H3 ANW can be used to test and learn from new tactics.

The LCS platforms assigned to TF02 approach the Strait from the West, and have IW that a number of fast patrol boats (FPBs) and missile boats (PTGs) operate in the vicinity of the Bandar Lengeh base. As such, both MH-60Rs from each platform are outfitted with eight Hellfire missiles in preparation for their ASUW patrols and engagements.

2. Steregushchiy Class Frigate

In LTJG Ozdemir’s Salvo Equation model, Steregushchiy, like LCS, had no SSMs on board, making the only offensive missile the air-launched Hellfire with a striking power of eight. ASW role striking power is 12 torpedoes, which is a sum of eight tubes on the ship and four torpedoes on the helicopter. Defensive power is 7.7 against a SSM firing enemy, composed of four 30 mm CIWS, eight short-range IR SAMs, and a 100 mm gun. The staying power against lightweight torpedoes and long range SSMs is 1.6 and short range SSMs is 2.5.

In the H3 ANW model, Steregushchiy is almost a completely different platform. The capabilities of the platform are designed under a Harpoon database (DB) written and developed by a collection of individuals from the *HUD3 – Harpoon 3 ANW Database* website. The Harpoon Users' Database series (HUD), grew out of the initial on-line community attempts to make corrections to previously released databases and is regarded as one of the best sources for online scenarios and DBs. The Steregushchiy was only available on the HUD3 DB. For this model, attempts to copy the platform specifics from the HUD3 DB into the H3 ANW DB proved impossible. As a result, the author attempted to design a platform with the same characteristics. The depth and detail of information in H3 ANW platform design was driven home. The resulting platform, has all of the capabilities and characteristics of the original HUD3 DB design, but is considerably different from the platform used in the Salvo Equation model. Most notably is the use of the KA-27 Helix verses the MH-60R Seahawk for helicopter operations.

B. OPPOSING FORCE MODEL ASSUMPTIONS AND LIMITATIONS

As mentioned, OPFOR was designed in the form of two TFs (See Figure 21); approaching as four waves of attackers for the Salvo Equation model, and a single complete force for the H3 ANW model. In TF 480, there are two PTGs forming TG 480.4 and six PGFGs forming TG 480.2. Two classes of submarines totaling five vessels, are broken up with two Kilos forming TG 480.1 and three Yonos forming TG 480.3. The major threat from TF 480 comes in the heart of the Strait. This is due to the concentration of submarines and the large number of overlapping missile ranges from the other vessels.

TF 490 operations in the western part of the Strait are bound to the Bandar Lengeh base and more limited in scope. These operations are modeled to attack in two waves under the Salvo Equations model. TG 490.01 consisting of four Thondor class PGFGs comprise the first wave while TG 490.02 with three PTGS forms the second. Once again, in the H3 ANW model, there is no distinction between the waves of attackers despite limitations placed on the range of patrol operations. The purpose of this TF is to swarm the FRIFOR ships, saturating their defenses and creating an opening to attack tankers or other merchant vessels being screened. Since this combined TF included PGFGs and PTGs, their striking power (C-802s and C-701s), defensive power (large caliber guns on Thondor classes), and staying powers were homogenized in the Salvo Equations model. Detailed calculations are shown in Appendix C of Ozdemir (2009).

The following information describes the assumptions and limitations of each attacker within TF 480 and TF 490.

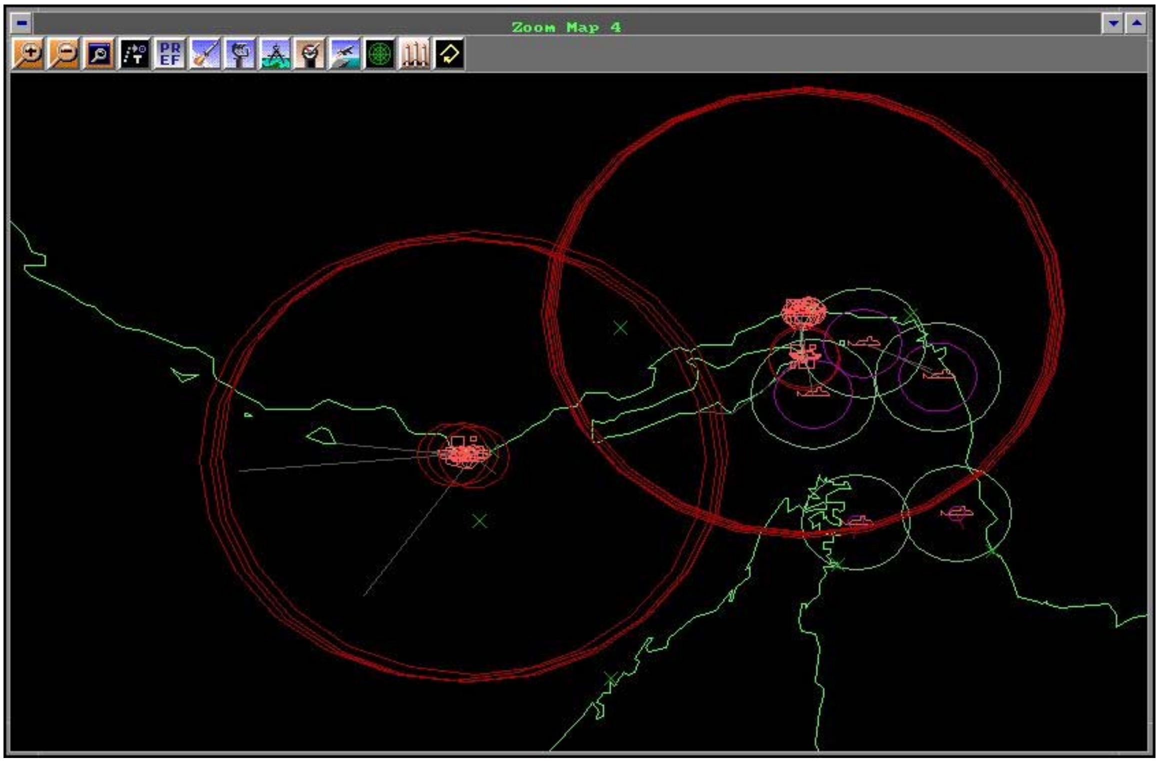

Figure 21. OPFOR Within Strait of Hormuz with Weapon Ranges Displayed (Best Viewed in Color)

1. TG 480.01: Kilo Class SSK

Both Kilo submarines allocated from Bandar Abbas are involved in the initial wave. The submarine has six torpedo-launching tubes and given a striking power of six, while defensive and staying power were both one in the Salvo Equation model. Based upon their stealth capability, it was expected that the submarine threat would need to be eliminated by conventional ASW forces before littoral operations began. Salvo Equations vividly showed the dominance of the submarines in ship versus submarine encounters. It showed that very few numbers of submarines can pose a serious threat and a large number of ships are required to dominate the encounter (Ozdemir, 2009).

The H3 ANW model initially displayed the same results. One or two Kilos would destroy any surface platform that came within range, usually without being detected. Once the LCS platform was specifically assigned to the ASW mission and configured to use an MH-60R in an ASW capacity, the Kilos were systematically prosecuted and destroyed. The key was defining the ASW mission. Once engaged in this manner, the LCS platforms used the tactic of staying outside of the sub threat zone and directing the MH-60Rs to conduct search and detection followed by prosecution. The Steregushchiy platform performed well also, again once specifically assigned to an ASW mission. Until the ASW mission was entered as the mission for these platforms; however, they tended to move right into weapons envelopes of the Kilos.

2. TG 480.02: Kaman Class PGFG

Also operating from Bandar Abbas, six ships are used in this model. Since they have the long-range SSMs, they are the second encounter in the Salvo Equations. Striking power is designated as four C-802 long-range SSMs. Limited to a single 76 mm gun, defensive power is only two. Staying power is one against long range SSMs and 1.5 against Hellfires.

In H3 ANW a visual representation of these platforms in the environment quickly made it obvious that the range of the C-802s would overlap the operating sectors for some of the other OPFOR assets. In fact, their range covers a significant portion of the region, which serves to highlight the inherent danger of conducting operations within such a strategic choke point and confined waterway.

3. TG 480.03: Yono Class SSC

All three of these midget submarines were expected out of Bandar Abbas. After the initial two waves of attackers, FRIFOR ships move towards the Iranian mainland, where the Yono class subs pose the third threat. Assumed to be carrying two torpedoes, the striking power is two, the defensive power and staying power was one, the same as a Kilo submarine in the Salvo Equation model.

In the H3 ANW model, this platform does not exist. It is one of the platforms specifically user designed for the model. The three created platforms operated as expected and provided a capable threat against surface platforms. Their area of operation was limited with the Yono's dependence on shore support taken into account. As with the Kilos, they pose a credible threat against the surface forces until the surface platform and their air assets are tasked with ASW missions.

4. TG 480.04: C-14 PTGs

As the fourth wave of attackers, a total of two PTGs operated out of Qeshm Island. Their striking power of 2.8 comes from their loadout of C-701s. Their defensive and staying power are both one.

The H3 ANW database has a version of this platform available, but it is incomplete. Modifying its characteristics and weapon loadout was accomplished through the use of the Database Editor. Designed to operate closer to shore than the Kamans or Thondors, the C-14s provide a small, fast, and capable platform that covers a large portion of the choke point.

5. TG 490.01: Thondor Class PGFGs

The first attack wave in the western region is the combination of the four available Thondor class ships from Bandar Lengeh. The Striking power of the class is four C-802s. Due to rapid firing medium caliber guns, Thondor’s defensive power is two, and staying power was 1.2.

A similar platform was used from the H3 ANW database as the guideline for developing this platform. Using the platform information from Jane’s, the Thondor was added to the library with the strike capability of C-802s. As with the Kaman class, these vessels are fast, have greater range to conduct operations, and can target and destroy FRIFOR surface combatants at a much greater range. Again, the C-802s provided the ability to cover a large percentage of the region. For this thesis scenario, four of these PGFGs patrol the western entrance to the Strait of Hormuz.

6. TG 490.02: C-14 PTGs

The second attack wave in the western region was the three C-14 PTGs out of Bandar Lengeh. Just as with TG 480.4, the striking power of 2.8 comes from the C-701s, while their defensive power and staying power were one.

See Section 4. TG 480.4 for data pertaining to the development of this platform within H3 ANW. Due to their limited range, this TG operates close to shore, but provides a credible missile threat to FRIFOR despite the shorter range of the C-701s compared to the C-802s. These platforms still manage to adequately cover the western entrance to the Strait of Hormuz.

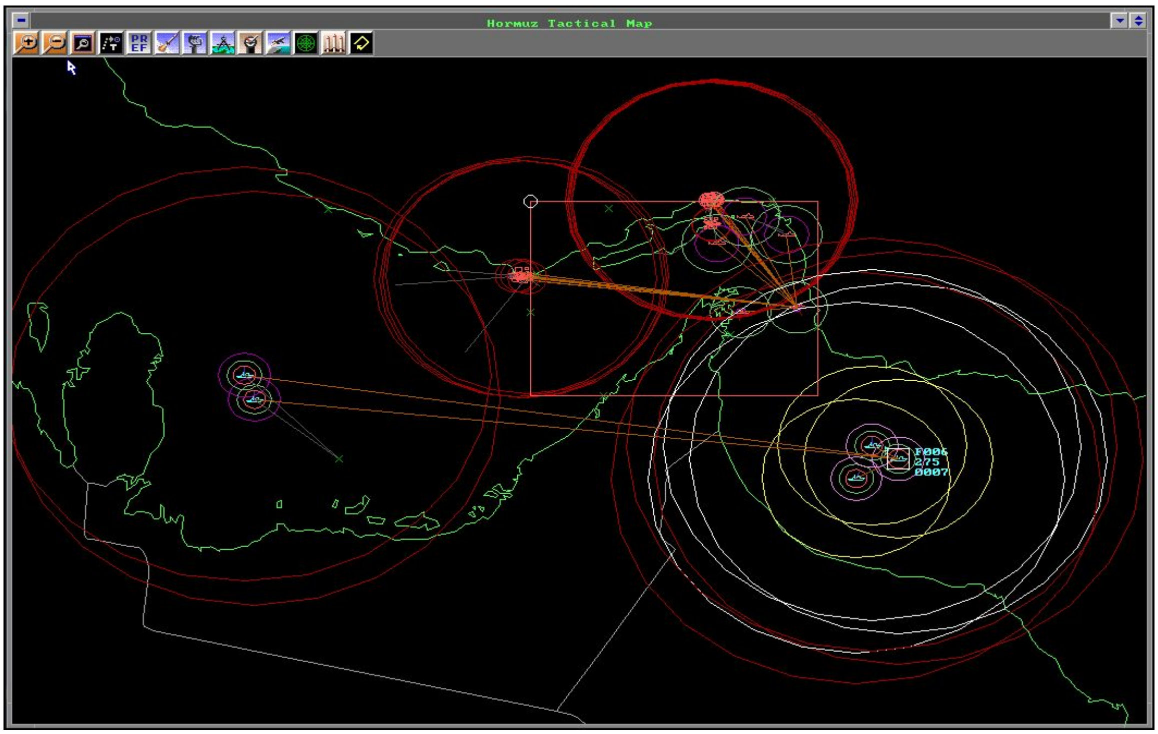

Figure 22. Scenario Overview With Weapon Ranges and Sensors Displayed (Best Viewed in Color)

C. MODEL EXECUTION

In this section, the model execution and observations are explained. Inputs for this model are based upon the Strait of Hormuz scenario previously described and the specifications of the vessels detailed in Appendices A and B.

1. Scenario Geography

Harpoon3 ANW’s Scenario Editor allows the model to be developed using the correct longitude and latitude to provide a visual representation of the Strait of Hormuz (see Figure 22). Various features of the Map Preferences provide a number of additional features. Depth of water or elevation of land can be displayed, affecting what platforms can be effectively employed within a geographic location. Weather and Sea State are environmental factors that were developed into the scenario. Unlike the Salvo Equations, which do not directly account for environmental factors, this model explicitly uses these to affect scenario execution. Sea State forces some of the smaller platforms, not designed for operations in higher sea states, to be limited in their operations. Weather in the form of fog or precipitation provides modifiers that affect the visual line-of-sight (LOS) of vessels, as well as how well radar and sonar operate. Depth of water effects how submarines can operate, and in this scenario, limits their depth of operation. It is believed this is a contributing factor to how well the MH-60Rs are able to search for and destroy the OPFOR submarines. Additionally, the simulation clock keeps track of time of day, resulting in operations conducted in reduced visibility of darkness.

The dynamics of real-world interactions within the model, environmental factors and geography affecting platform performance, provides great insight into considerations that must be addressed while conducting combat operations. H3 ANW provides an excellent tool for experimenting and learning how these factors affect a mission’s outcome.

2. Scenario Platforms

The Database Editor, based upon Microsoft Access software, allows the designer to develop and use a number of platforms: including manned and unmanned aircraft, surface combatants, and submarines. Additionally, numerous instillations and facilities are provided for entering a known base or creating a new one when designing a scenario. Along with all of these platforms, there is a vast index of weapons available for each platform. H3 ANW provides detailed explanations for each platform and weapon, to include who originally designed it, which country has produced or modified it, and what countries throughout the world are known to use it.

For this thesis, designing a new platform proved harder than expected. Specifically, designing a platform that operates similar to an actual platform was difficult. The database is so extensive and requirements so specific that correct type and number of engines and appropriate grade of fuel must be specified. Batteries for the various submarine platforms varied in their power output and recharge rate. Weapon assignment to a platform is tightly controlled in regards to what platforms are capable of carrying a specific weapon. Although educational benefits regarding platform capabilities, both strengths and weaknesses, were achieved, this process is cumbersome and extremely time consuming.

The strength of H3 ANW's Database Editor is that it is modular in design, can be augmented with new platforms and multiple databases are up to date by a number of outside sources. Along with these databases, hundreds of readymade scenarios are available for download and play. These scenarios are designed around current events ranging from engagements involving Maritime Interdiction Operations (MIO) in support of NATO resolutions to providing protection of trade routes and pirate interdiction.

The platforms used in this thesis helped display the very real threat the United States Navy faces within strategic choke points and littorals. The asymmetrical OPFOR threats present in the Strait of Hormuz were used to demonstrate what FRIFOR tactics provide the greatest probability for mission success.

3. Scenario Engagements

The engagements in this model focused on FRIFOR attempts to remove the threat posed by OPFOR assets within the Strait of Hormuz. (See Figure 22) It should also be noted that all engagements occurred without human interaction, but rather under guidelines developed for the artificial intelligence using a Weapons Free posture. As previously described FRIFOR platforms receive IW on what potential threats are posed within the littoral. Based upon this intelligence, FRIFOR tactics used two task forces to approach from both the West and East entrances to the Strait.

TF01 approaches from the East and is designed to combat the expected submarine threat and any OPFOR surface combatants present. Upon model execution, the platforms assigned to TF01 cruise into the submarine threat zone, where the Kilo and Yono submarines held the tactical advantage. In these cases, the OPFOR submarines remain undetected and launch torpedoes at FRIFOR vessels. LCS ships react quickly and use tactics to avoid total loss of force while returning fire. Steregushchiy frigates do not react as quickly; discussed further in the next section. Both platforms demonstrated marked improvements once a clearly defined ASW mission was designed for the TF.

H3 ANW allows a user to build a mission focused on operations such as ASW, ASUW, Recon, etc. Once assigned a mission, the platform operates according to established tactics designed to counter the expected threat. Specifically for this model, as soon as TF01 was assigned to an ASW mission, the vessels stayed near the edge or completely outside of the defined submarine threat zone, and used airborne assets to hunt and prosecute OPFOR subs. The airborne assets consist of two MH-60R helicopters for LCS, and one KA-27 Helix helicopter for the Steregushchiy.

TF01 also has to deal with the OPFOR surface threats in the form of Kaman FPBs and C-14 missile boats. To combat this threat, one MH-60R from each LCS is assigned an ASUW mission with a weapons loadout of eight Hellfire missiles. The other MH-60R helicopter for each LCS platform is assigned to the previously mentioned ASW mission with a weapons loadout of two Mk-54 torpedoes. The KA-27 Helix is limited to carrying only torpedoes, and do not provide any benefit towards the ASUW mission other than sensor and visual identification of surface contacts. At this time, it is not clear if this is a limitation of the platform itself, or simply a limitation of the way the platform has been designed in H3 ANW.

TF02 approaches from the West and is designed to combat the expected threat of OPFOR surface combatants. Upon model execution, TF02 was assigned to a well-defined ASUW mission with the MH-60R helicopters armed with eight hellfire missiles each. Unlike with the ASW mission, the LCS actively prosecutes surface contacts, while using the airborne assets as the primary offensive weapon. Several runs involved the LCS closing OPFOR surface forces and engaging in direct fire against the Thondor and C-14 vessels with 57 mm Mk 110 gun system.

This model was designed with specific ASW and ASUW mission areas defined through the H3 ANW user interface. These zones overlapped based upon the geography and threat location. Both TFs used their airborne assets as primary weapons and as a result occasionally suffered the loss of a helicopter to gunfire from the Kaman or Thondor platforms. The number of FRIFOR surface combatants used was varied from one to five platforms in each TF. In all cases, once the mission specifics were clearly defined, all platforms adopted the tactic of standing off and using the helicopters to engage OPFOR assets.

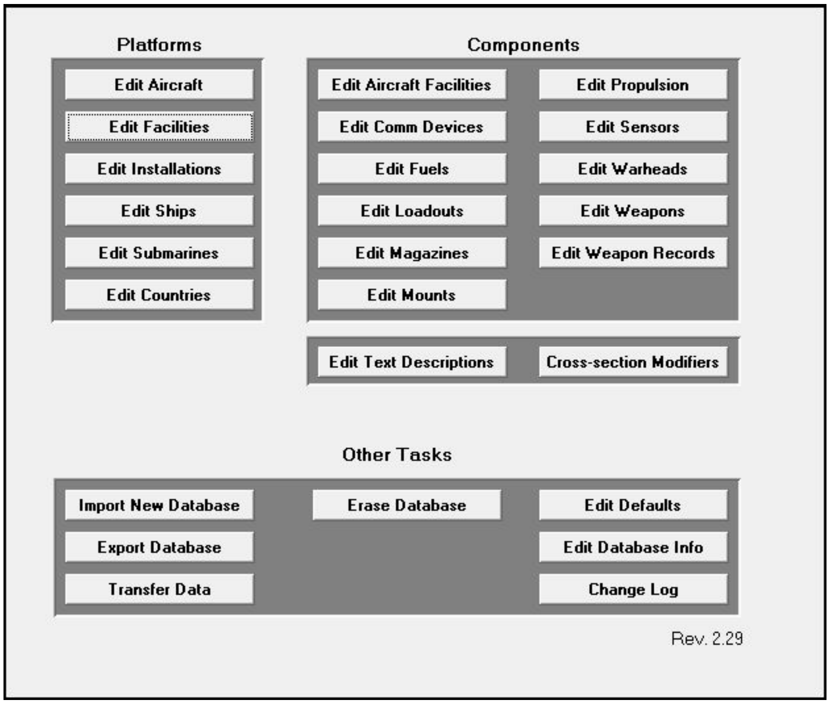

Figure 23. Harpoon3 ANW Database Editor

4. Scenario Observed Problems

In designing the model, several problems were encountered during development or model execution. First and foremost was the H3 ANW Database Editor. The editor appeared better at modifying platforms as opposed to creating new ones. It is not intuitive how to develop new platforms, and in fact proved to be quite a challenge. The initial form for navigating platforms is easy to follow, but actual platform design data is not user friendly. (See Figure 23) Designing a vessel from scratch requires knowledge of specific platform characteristics including sensor version, fuel types, etc. If parameters were not available, approximations were required with probability that the platform did not perform as specifically as the real-world vessel.

In an effort to gain as much detail as possible, the model was designed using platforms from the H3 ANW Database. Any incomplete data was approximated based upon class characteristics of similar vessels. Steregushchiy frigate data was obtained from the Harpoon Users' Database 3 (HUD3) which is downloadable from the Advanced Gaming System's Harpoon Users' Database website. Importing complete data from one database to another proved unachievable; as a result not all of the platform specifics were transferred. Missing characteristics were entered into the H3 ANW Database by the author. Upon model execution, Steregushchiy did not perform as well as expected given the platform's potential capabilities. It is surmised the designed platform is not as robust as is required to emulate the real-world asset accurately. Further design development may enhance its performance in future models.

Problems caused by geography occurred upon initial execution of the model. The first scenario designs placed the FRIFOR assets just outside of the Strait of Hormuz, poised to enter and conduct operations. Upon activation, the first event to occur was multiple C-802s launching at the FRIFOR platforms, whose Close-In-Weapons-Systems (CIWS) began to engage incoming missiles. Simulating a combat information center (CIC) atmosphere, staff messages concerning incoming vampires and pop-up targets filled the message screen. This first run resulted in the two FRIFOR platforms being destroyed within the first 30 seconds of model execution. FRIFOR units began further outside threat envelopes and were guided by specific mission criteria for all subsequent runs.

Specific platforms problems were previously mentioned; however, it is possible some of these occurred due to the method of model execution. Both forces were designed with specific missions, to identify each other as hostile in a weapons free posture. The model was executed with all units operating independent of guidance from a real-world user. As a result, some of the platforms did not operate as might be expected if an intelligent adversary were operating them. Submarines, which should have had a tactical advantage based upon stealth and superior passive sensors, did not press the advantage or engage when it appeared they should. This may be due to some of the transparent calculations that occurred, but it is expected that an intelligent advisory would operate differently.

Clearly, the primary FRIFOR asset, helicopters occasionally would identify a target through the use of deployed sonobuoys or other sensors, but would continue along their planned search pattern rather than prosecuting the contact. Additionally, helicopters would identify a surface contact as hostile and then fly within its weapons range, to be shot down. The primary cause for helicopter loss was fuel capacity. They would conduct their mission, reach Bingo fuel, and have to ditch the aircraft while in route back to their ship. Helicopters attempting to land on platforms other than their assigned ship were not observed. It is understood that in real-world operations this would help enhance the mission capability of the helicopters.

The last problem encountered in designing the model was in correctly implementing Victory Conditions (VC), the criteria or mission objectives to be met in order to achieve mission success. The Scenario Editor allows for several options, which must be defined for all forces involved in the engagement. These victory conditions can be in the form of completing a transit with either no or a acceptable percentage of losses, protecting high-value assets throughout a transit, forces surviving for a period of time, or a number of other combinations. For both FRIFOR and OPFOR, this model defined the VC as 100 percent destruction of the adversary’s platforms; 20 for OPFOR and varied numbers for FRIFOR. Initially defining the VC proved problematic. Attempts to specify the number and names of each OPFOR platform resulted in FRIFOR’s inability to obtain VC, despite having destroyed all of the OPFOR platforms. It is unclear if this was an error on the part of the simulator or in the design specifics. Adjustments in defining the VC as a generic list of submarines and surface ships allowed the FRIFOR assets to meet the defined VC.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSION

This thesis is the applied efforts of conducting a comparative analysis of commercial off-the-shelf naval simulations and classic operations research models. The focus of comparison was on the use of the naval simulation software Harpoon 3 Advance Naval Warfare (ANW). This thesis attempted to use H3 ANW to emulate the research results obtained by Ozdemir (2009). It also attempted to gain insights into how this cost-effective simulator may be used to help today's Surface Warriors understand the asymmetric threats they may be faced with when conducting naval operations within strategic choke points and the littorals around the world.

1. Benefits of Off-the-shelf PC-based Simulators

In an article titled, *Time for the Navy to Get into the Game!,* published in U.S. Naval Institute's magazine *Proceedings (April 2009)*, Captain Mark Woolley, USN, wrote about the benefits PC-games can provide to naval training. He states that PC-based simulators are not a replacement for actual drills and exercises or expensive land-based simulators, such as those for fire fighting, damage control, seamanship and navigation. Nor are they intended to replace current embedded on-board training systems, like those associated with combat and engineering systems. They do, however, provide several distinct advantages for training that have yet to be fully realized.

First, they can make more effective use of costly simulator time by ensuring students have the basics before using the simulator. PC-based games use scenarios to build competency and leadership skills, thereby improving the effectiveness of drills and exercises conducted in simulators or on board a ship. Second, they have the advantage of providing realistic training for specific equipment, consoles, and platforms. They provide an opportunity to refresh skills on a periodic basis, especially when the land-based simulators are not available or it is not possible to bring up shipboard systems or take systems off-line for dedicated training (e.g., shipyard or underway operations). Last, they provide a learning platform that is more appealing to the majority of younger generations than other forms of media. They offer an additional forum for Sailors to learn and increase their professional expertise. Furthermore, with the proliferation of personal laptop computers, they permit Sailors in cases where the material is unclassified to learn at their own pace outside the normal training lifelines.

2. Harpoon 3 Advanced Naval Warfare

This thesis used the Harpoon3 ANW simulation software to recreate the model used by Ozdemir (2009) which conducted research using Modified Hughes' Salvo Equations. While a dynamic and highly detailed simulation, a direct comparison of results was not obtained. This is attributed to several factors, the first being the different approaches used by the tools.

Salvo Equations assign specific homogeneous values for Striking, Defensive, and Staying Powers, as well as

Scouting, Readiness, Training and even Leaker rates (See Chapter II for more detailed explanations) to scenario specific heterogeneous Opposition Forces (OPFOR) and Friendly Forces (FRIFOR). H3 ANW uses an intricate series of tabulated formulas, reference tables, and modifiers to model dynamic interaction between forces. The Salvo Equations model is able to isolate successive waves of OPFOR assets, assigning specific values to each and allowing FRIFOR assets to rearm and refuel between each engagement. The H3 ANW model produces a dynamic interaction that has OPFOR patrol areas and weapons ranges overlapping. It also allows for FRIFOR platforms to use specific tactics when engaging OPFRO threats. The use of dedicated anti-submarine warfare (ASW) and anti-surface warfare (ASUW) patrols and tactics marked a profound difference in the outcome of each model run. Whereas the Salvo Equation model provided insights through the use of mathematical calculations, and was instrumental in defining the scenario for this thesis, H3 ANW provided insights into specific platforms capabilities and limitations, employed tactics, environmental factors, and geographic concerns when conducting operations within strategic choke points and littorals around the world.

3. Harpoon 3 Professional

Harpoon 3 Professional (H3Pro) is another development of the Harpoon 3 game engine, which has extensive changes incorporated for use by the defense industry. It will not be available to the general public and will be published by Advanced Gaming System Inc. (AGSI) H3Pro features enhancements requested by AGSI’s military customers. The most popular application is to extend modeling and simulation capabilities already in place. Existing simulation software tends to be precise and requires a commensurate level of staffing for effective use. When an analyst needs to take a broad look at a problem and run many scenarios, the “heavy” tools take too long and do not allow for adequate coverage. H3Pro runs at a lower fidelity, thus faster, and with a much smaller footprint. This means an analyst can survey a problem space quickly and easily, and then bring the “heavy” tools to bear on a better-defined problem (Computerharpoon.com/wiki).

H3Pro embodies the latest in naval warfare simulations for analysis, education and training. Among the new features are programmable mission behaviors, a new mission type allowing for boarding of ships by helicopter, thereby simulating special operations. Users may then simulate situations taken from today’s headlines, such as fighting Somali pirates or interdicting drug runners who use submersibles. Customization is available, and both the databases and scenarios are open for end-user editing. AGSI states that they have former defense experts available to assist in training, configuration, design and execution.

Some of the improvements touted by AGSI include:

1. Geospatial Information Systems (GIS) Interface: Allows simple geometric shapes to be imported from products such as ESRI's ArcInfo

2. Harpoon Track Interface (HTI): Unit tracks can be exported to a standard database product and then to products such as Satellite Tool Kit (STK)

3. “Hot Wash-up” or “VCR”: Provides the ability for entire games to be recorded, viewed, edited and replayed

4. Structured Query Language (SQL)

5. Distributed Interactive Simulation (DIS) Interface: International standard used for simulations to communicate in real time

6. Umpire functionality providing the ability for a training professional to oversee training activities

B. RECOMMENDATIONS

Junior officers in the United States Navy Surface Fleet are taught the basics of naval warfare, communications, and tactics. It is not until later in the leadership pipeline that they are exposed to specific tactics and methods for combating the threats faced by naval professionals. Taught to regurgitate specific details while earning the Surface Warfare Officer (SWO) qualification pin, many officers never have the opportunity to learn what those platforms can do, how they are employed, and what potential threats they are susceptible to. Unfortunately, there are those platforms such as the USS VINCENNES, USS STARK, and USS COLE who know all too well the harsh lessons learned from real-world operations.

For junior officers, all of their training and studying culminates in book knowledge presented before a unit’s SWO qualification board. What value and insights could be gained by allowing Surface Warriors to participate in training through the use of simulated scenarios? How much more professional and alert would a vessel’s leadership be after having conducted an operation where they watched their ship overwhelmed by small missile boats while conducting a transit though a strategic choke point? The benefits of allowing a ship’s wardroom to actually participate in and see the threats they may face would be an eye-opening experience for many, while helping to sharpen warfighting skills.

The Harpoon3 ANW/Pro series of naval simulations provides an inexpensive aggregated training tool that can benefit today’s United States Navy. It provides scenario based training that can be tailored to operations within specific geographical locations, demonstrate upcoming ship’s evolutions, or educate leadership on scenarios right out of the headlines (e.g., Somali pirate interaction). The potential as a cost effective training tool to introduce Surface Warriors to the asymmetric threats they face today has yet to be realized.

C. FUTURE STUDY

The original intention of providing an analytical comparison between results gained from a model using Hughes’ Salvo Equations and the output of a similar scenario using the off-the-shelf naval simulation software Harpoon 3 Advanced Naval Warfare (H3 ANW) was not realized. Instead, what was gained is a better understanding of the mathematical nature of Hughes’ Salvo Equation models and the dynamic interaction of an intelligent software tool such as H3 ANW. The insights and education that was gained in regards to platform capabilities, weapons employment, and mission specific tactics was a direct result of experimentation while designing and executing a real-world scenario. (See Figure 24.)

Future analysis can include enhancing the scenario by further refining the available platforms, adding threats such as shore-based C-802s, incorporating fixed-wing aircraft, and developing platforms that demonstrate the capabilities of semi-submersible boats used by Iran. Additionally, a comparison of results between scenarios developed for Harpoon3 ANW/Pro with similar scenarios executed using agent-based distillation models with the aim of verifying or challenging the results obtained by Harpoon3 ANW/Pro simulation software. Finally, assessment of a multi-player feature of H3 ANW can be conducted. Scenarios involving multiple user interfaces may provide greater insight into the potential use as a training tool, and avoid scenario situations involving AI dogma. The added complexities of a human-in-the-loop opponent will most certainly add to the overall robustness of the model.

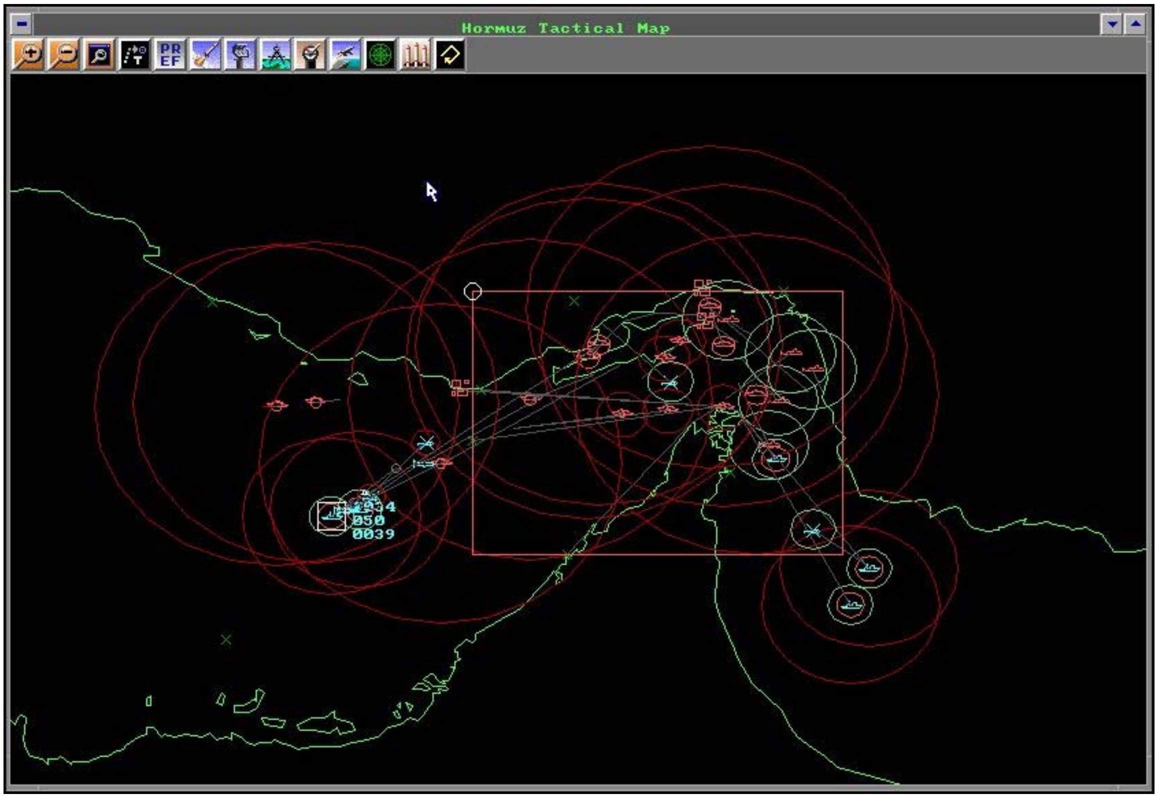

Figure 24. Strait of Hormuz Tactical Picture at Height of Combat Engagement (Best Viewed in Color)

APPENDIX A. FRIENDLY FORCE ASSETS

A. FREEDOM CLASS LCS FLIGHT 0

USS Freedom (LCS-1), built by Lockheed Martin in Marinette Marine, Wisconsin, was commissioned on 8 November 2008. USS Forth Worth (LCS-3) is due to be commissioned in 2013. A total of 55 LCSs is proposed.

Displacement	3089 tons, full load
Dimensions	115.3 m x 13.1 m x 3.9 m (Length, Beam, Draft)
Main Machinery	CODAG; 2 GT (96550 hp), 2 Diesels (17160 hp), 4 Water jets
Speed, Range	45 Kts, 3500 NM at 18 Kts
Complement	50+25 mission package crew and aircrew
Missiles	1 RAM RIM-116, 21-cell Mk 99 launcher, Passive IR/anti-radiation homing to 5.2 NM at 2.5 Mach, Warhead 9.1 kg,
Guns	1 57 mm/70 Mk 2, 220 rds/min to 9 NM, shell weight 2.4 kg, 4 12.7 mm MG
Countermeasures	2 SKWS/SRBOC decoy launcher, ESM/ECM
Helicopters	2 MH-60 R/S Helicopter or 1 MH-60 R/S and 3 MQ-8B Fire Scout VTUAVs
Notes	7 Mission Modules (3 MW, 2 ASW, and 2 ASUW) are to be used interchangeable on LCS. Capability to launch and recover manned and unmanned boats.

Table 10. Freedom Class LCS Characteristics

Figure 25. USS Freedom-1 (LCS-1), from JFS

Figure 26. USS Freedom-2 (LCS-1), from JFS

B. STEREGUSHCHIY CLASS (PROJECT 20380) FRIGATE (FFGH)

RS Steregushchiy (F-530), built at Severnaya, St. Petersburg for the Russian Navy, was commissioned on 14 November 2007. Four more of this design are being built and will be commissioned between 2010 and 2011. Two more are proposed.

Displacement	2200 tons, full load
Dimensions	104.5 m x 11.1 m x 3.7 m (Length, Beam, Draft)
Main Machinery	CODAD; 4 Diesels (24000 hp), 2 shafts
Speed, Range	26 Kts, 3500 NM at 14 Kts
Complement	100
Missiles	1 CADS-N-1 Kashtan, twin 30 mm Gatling combined with 8 SA-N-11 Grisson, laser beam guidance to 4.4 NM, warhead 9 kg, 9000 rds/min for guns
Guns	1 100 mm, 80 rds/min to 11.6 NM, shell weight 15.6 kg, 2 30 mm/65 AK 630 CIWS, 3000 rds/min, 2 14.5 mm MG
Torpedoes	8 324 mm tubes, anti-torpedo active/passive homing to 2.7 NM, warhead 70 kg
Countermeasures	4 PK 1- launchers, ESM/ECM
Helicopters	1 Ka-27 Helix
Notes	Space is provided for 8 SS-N-25 SSMs

Table 11. Steregushchiy Class Frigate Characteristics

Figure 27. RS Steregushchiy-1 (F-530), from JFS

Figure 28. RS Steregushchiy-2 (F-530), from JFS

C. SIKORSKY MH-60R SEAHAWK

MH-60R Seahawk is built for the U.S. Navy to replace the aging SH-60B/F fleet. It will serve as the future tactical helicopter operated from surface combatants. Entered in the frontline service in 2006, MH-60R is equipped with a full-spectrum of airborne sensor suits, equipments and weapons for principal naval warfare. Recent product improvements to the helicopter include a fourth weapons station, allowing a total of eight AGM-114 Hellfire missiles or four Mk-54 torpedoes. Besides the modern sensors and lethal weapons load, having an operational speed of 145 knots and a range of 450 NM, MH-60R Seahawk is one of the most effective tactical helicopters operated from ships.

Figure 29. MH-60R Seahawk, from JFS

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APPENDIX B. OPPOSING FORCE ASSETS

A. KILO CLASS (PROJECT 877 EKM) SUBMARINE (SSK)

Three Kilo class submarines were built for the Iranian Navy by the Admiralty Yard in Saint Petersburg and commissioned in 1992, 1993 and 1996.

Displacement	3076 tons dived
Dimensions	72.6 m x 9.9 m x 6.6 m (Length, Beam, Draft)
Main Machinery	2 Diesels (3650 hp), 1 electric motor (5500 hp), 1 shaft
Speed, Range	17 Kts dived, 6000 NM at 7 Kts snorting
Complement	53
Torpedoes	6 533 mm tubes, combination of TEST-71/96 wire guided active/passive homing to 8.1 NM at 40 Kts, warhead 220 kg and 53-65 passive wake homing to 10.3 NM at 45 Kts, warhead 350 kg. Total of 18 torpedoes. 24 mines in lieu of torpedoes.
Notes	Chinese YJ-1 or Russian Novator Alfa SSMs and SA-N-10 SAMs may be fitted during the planned upgrade refit of the boats.

Table 12. Kilo Class Submarine Characteristics

Figure 30. Iranian Kilo Class Submarine-1, from JFS

Figure 31. Iranian Kilo Class Submarine-2, from JFS

B. YONO CLASS (IS 120) COASTAL SUBMARINE (SSC)

Based on the North Korean design, a total of five submarines are claimed to have been built in Iran with one more under construction. First noticed in 2004, little is known about these boats.

Displacement	123 tons dived
Dimensions	29 m x 2.8 m x 2.5 m (Length, Beam, Draft)
Main Machinery	Diesel-electric
Complement	32
Torpedoes	2 533 mm tubes

Table 13. Yono Class Submarine Characteristics

Figure 32. Iranian Yono Class Submarine, from JFS

C. KAMAN (COMBATTANTE II) CLASS FPB (PGFG)

Ten boats were built by CMN in Cherbourg, France for the Iranian Navy and commissioned between 1977 and 1981. Three more of this class were built by Iran at Bandar Anzali on the Caspian coast and commissioned in 2004, 2006 and 2008.

Displacement	275 tons full load
Dimensions	47 m x 7.1 m x 1.9 m (Length, Beam, Draft)
Main Machinery	4 Diesels (12280 hp), 4 shafts
Speed, Range	38 Kts, 2000 NM at 15 Kts
Complement	31
Missiles	2 or 4 C-802, active radar homing to 66 NM at 0.9 Mach, warhead 165 kg
Guns	1 76 mm/62, 85 rds/min to 8.7 NM, shell weight 6 kg, 1 40 mm/70, 300 rds/min to 6.6 NM. Some have 23 m or 20 mm gun in place of 40 mm. 2 12.7 mm MG
Notes	SA-7 portable SAMs maybe embarked. Latter built boats are stationed in Caspian Sea.

Table 14. Kaman Class FPB Characteristics

Figure 33. Iranian Kaman Class FPB-1, from JFS

Figure 34. Iranian Kaman Class FPB-2, from JFS

D. THONDOR (HOUDONG) CLASS FPB (PGFG)

Ten boats were built for the Iranian Navy at Zhanjiang Shipyard, China and commissioned in two batches in 1994 and 1996.

Displacement	205 tons full load
Dimensions	38.6 m x 6.8 m x 2.7 m (Length, Beam, Draft)
Main Machinery	3 Diesels (8025 hp), 3 shafts
Speed, Range	35 Kts, 800 NM at 30 Kts
Complement	28
Missiles	4 C-802, active radar homing to 66 NM at 0.9 Mach, warhead 165 kg
Guns	2 30 mm AK 230, 2 23 mm MG
Notes	A similar design to Chinese Huangfen (Osa 1)

Table 15. Thondor Class FPB Characteristics

Figure 35. Iranian Thondor Class FPB, from JFS

E. C-14 CLASS MISSILE BOAT (PTG)

Nine boats were built by China State Shipbuilding Corporation and delivered starting in 2000. Five boats are likely to carry short range Chinese FL-10 SSMs, while the remaining four have a Multiple Rocket Launcher (MRL).

Displacement	17 tons
Dimensions	13.7 m x 4.8 m x 0.7 m (Length, Beam, Draft)
Main Machinery	2 Diesels (2300 hp), 2 shafts
Speed	50 Kts
Missiles	4 FL-10
Guns	1 20 mm, 1 12.7 mm MG
Notes	A catamaran-hull design

Table 16. C-14 Class Boat Characteristics

Figure 36. Iranian C-14 Class Missile Boat, from JFS

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